COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

APR 24 1942

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April, 1942

Slag-discharge ring in furnace bottom of large boiler

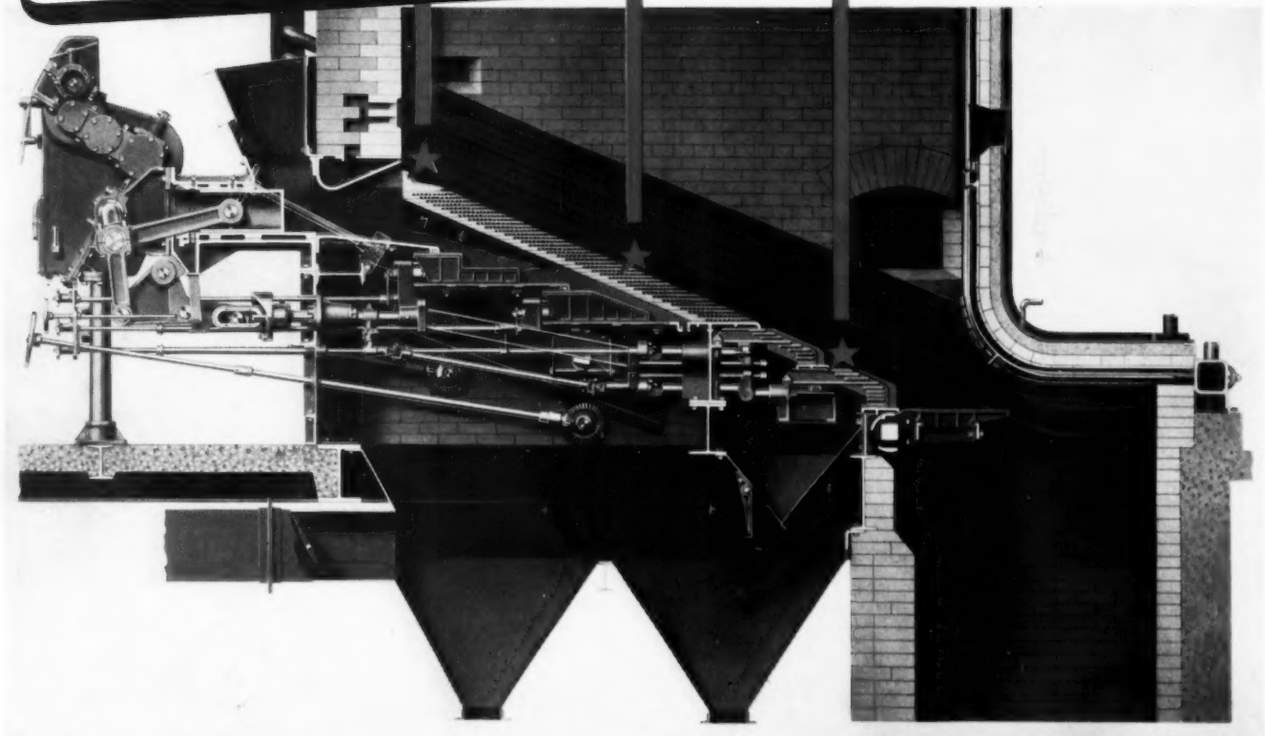
Combustion Calculations by Graphical Methods—U. S. COALS ▶

Automatic Control of Natural-Gas-Fired Power Boilers ▶

Avoiding Deposits and Corrosion in Regenerative Type Air Preheaters ▶

UNIFORM FIRE!

one reason for the *SWING* to C-E MULTIPLE RETORT STOKERS



The 1941 sales record reveals plenty of recognition for the high degree of mechanical perfection achieved in the design of the C-E Multiple Retort Stoker. There are many features responsible for this success.

One big reason is the uniform depth and even contour of the fuel bed which in the C-E Multiple Retort Stoker results from an unusually well coordinated design of underfeed, overfeed and ash discharge sections. This design provides for proper agitation and movement of the fire all the way from the ram box to the ash pit. Then, with provision for zone-controlled air admission, the result is a relatively thin and level fuel bed which assures complete and efficient combustion.

The superiority of the entire design is a reflection of C-E's extensive stoker experience which includes a total of 16,700 stokers of all types serving approximately 4,700,000 rated boiler horsepower. Other features of the C-E Multiple Retort Stoker will be shown in future advertisements.

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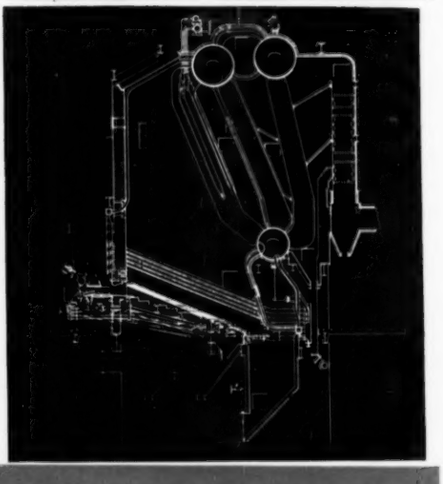

(At right)—Continuous Discharge Type C-E Multiple Retort Stoker with a C-E three-drum Boiler. 50,000 lb of steam per hr at 210 lb per sq in. at superheater outlet and 540F total temperature.

COMBUSTION ENGINEERING

200 Madison Avenue New York, New York

C-E PRODUCTS INCLUDE ALL TYPES OF BOILERS, FURNACES, PULVERIZED FUEL SYSTEMS AND STOKERS, ALSO SUPERHEATERS, ECONOMIZERS AND AIR HEATERS

COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

VOLUME THIRTEEN NUMBER TEN

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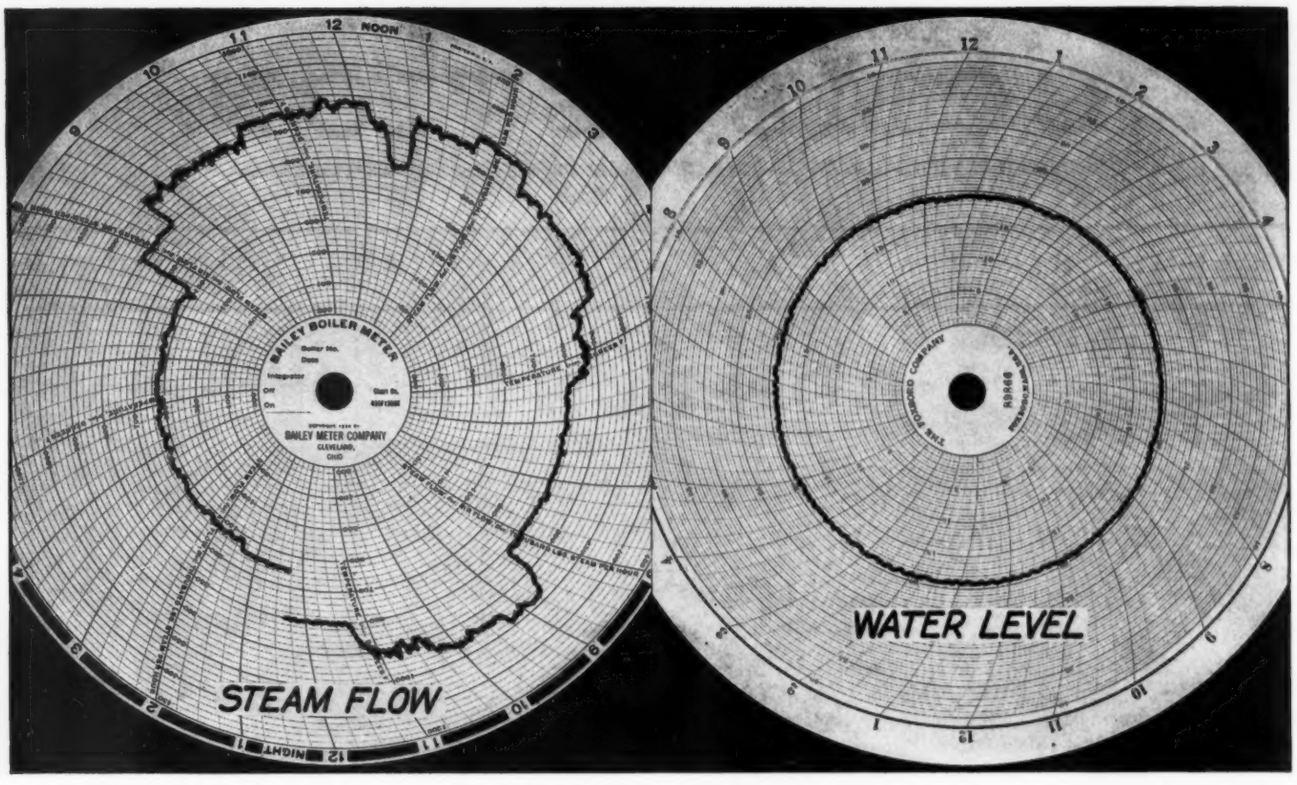

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FEEDS BOILER ACCORDING TO STEAM FLOW-AUTOMATICALLY

EDITORIAL

Power for War Production

It will be recalled that the program announced last summer by the Federal Power Commission envisioned the expansion of central station generating capacity by approximately 14 million kilowatts over a four-year period beginning with 1943. This was to have been made up of yearly additions of $2^1/_2$ million kilowatts of steam capacity and one million kilowatts of hydro capacity (mostly federal projects), in addition to the 6 million kilowatts then on order or under construction.

Of the latter, a total of $2^1/_2$ million kilowatts went into service during 1941, with private utilities accounting for 70 per cent; and about $3^1/_2$ million kilowatts was scheduled for operation in 1942, of which 60 per cent was to be additions by private utilities. That scheduled for operation this year included 900,000 kilowatts originally intended to go into service in 1941 but the installation of which was delayed.

At the time the plan was presented, there was some question as to the ability of existing turbine manufacturing facilities to meet the proposed program. Subsequently, despite a vast expansion in such facilities, naval and other marine demands have so multiplied as to interfere with scheduled deliveries of land turbines in a number of instances, and the materials situation, particularly as pertains to forgings, has also been responsible for some delay. At present such deliveries are being specified on project ratings by the Power Branch of the War Production Board to take precedence over previously issued priority ratings. This procedure is calculated to assure new capacity where and when it is most needed and the most recent order of the WPB has tentatively limited the 1942 stationary turbine-generator deliveries to approximately two million kilowatts.

In the controversy which ensued last year concerning the adequacy of power supply, many conflicting opinions served to becloud the issue, and other factors that have since developed could not have been foreseen. While, on the one hand, the magnitude of the war program has transcended all preconceived estimates; on the other hand, the present large-scale conversion of industrial plants to war production is making use of much existing power capacity. Also, many of the large government-owned munitions plants are being equipped with their own steam and electric generating facilities, and the physical transfer of surplus reserve equipment, as well as the diversion of equipment on order, are expedients that are meeting needs in special cases. Finally, the curtailment of non-essential electrical loads has been applied only in a few isolated cases and, in the aggregate, represents a pool that has scarcely been tapped.

As regards the program laid down last year by the Federal Power Commission, changing conditions have already dictated shifts in the distribution of capacity therein outlined. Whether or not events will justify installation of the total capacity prescribed, or its fulfillment will be possible, it is likely that means will be found to meet the most essential war demands for power. The Power Branch of the War Production Board appears to have the situation well in hand.

Engineering Meetings

One frequently hears the suggestion that the usual schedule of engineering meetings be curtailed, or in some cases deferred for the duration of the war; because most engineers are now too busy to prepare papers or to attend meetings, and restrictions imposed by censorship preclude many subjects that might otherwise be profitably discussed. In fact, a few associations have already cancelled scheduled meetings.

The logic of these contentions has some merit, since the output of most industries and the time of so many engineers are now given over entirely to war work. Yet there is another aspect to this situation that must not be overlooked. Never was there greater need for the dissemination of information that might be termed educational in the sense of meeting problems incident to the war. Inasmuch as education and the exchange of information are basic aims of an engineering society, as war production is primarily an engineering problem, and as those responsible for conduct of the war are striving by various means to provide such education, the opportunity for service of this character is clear.

Not only are existing processes finding new applications, but the dislocations brought about by scarcity of supply have presented many new problems which are being solved in ingenious ways. Furthermore, the sudden and vast expansion of production, coupled with personnel depletions because of the draft, have placed new responsibilities on many engineers who need all the assistance they can acquire. Much of this can be given through the medium of society papers and the technical press without violating censorship regulations.

This presents a somewhat different approach for program committees. If they are to make the most of present opportunities, they will disregard the peace-time habit of filling a program just to cover the various branches of the field and, instead, will direct their efforts toward those topics that are geared to present needs, not neglecting to keep in mind the application of war-time technology to post-war progress.

Admittedly, this is more easily said than done; but it should be possible to convince prospective authors who may have something pertinent to offer, that, notwithstanding demands on their time, they will be making a contribution toward the war effort. If the number of meetings is kept in line with the requirements; programs are thus carefully planned and entertainment features are held to a minimum, attendance should be assured.

It is the "convention as usual" attitude that has no place at present.

MIDWEST POWER CONFERENCE

This year the program, while dealing with the several branches of the field, such as steam, hydro power, electricity and internal combustion engines, placed special emphasis on problems brought about by the war. These included the adequacy of power supply, the maintenance of uninterrupted service under sustained heavy loads and with fuels often differing in characteristics from those for which the equipment was designed.

WITH the joint sponsorship of local sections of the national engineering societies and a group of midwestern universities, the 1942 Midwest Power Conference held its fifth annual two-day meeting at the Palmer House, Chicago, on April 9 and 10. The program, under the direction of **Prof. Stanton E. Winston,** was tuned largely to a discussion of power problems incident to conduct of the war. At the opening session the delegates were welcomed by **H. T. Heald,** President of Illinois Institute of Technology, and **Dean A. A. Potter** of Purdue University responded for the cooperating institutions, pointing out that the present conflict is a challenge to the talents of American engineers and industrialists as well as to our ideals and form of government, for our engineers are now confronted with the most complex problems of developing new techniques, new devices and new tools to serve military, naval and air service objectives.

Power Requirements

Leland Olds, Chairman of the Federal Power Commission, followed with the observation that it is not possible to put electric generating capacity into operation with anything like the speed with which the need for power may arise. The time required to manufacture and install generating equipment under present conditions precludes any hope of securing more capacity in 1942 and 1943 than is now actually on order and it is even doubtful if this capacity will be available as scheduled.

Referring to the long-range plan for power expansion submitted by the Commission last summer, he explained that this was predicated on the assumption that by 1943 defense expenditures would be at an annual rate of 36 billion dollars; that half this program would represent displacement of normal civilian supply; that, even using manufacturing capacity to the limit, the total loads in 1943 and 1944 could be carried only by cutting heavily into reserves and by considerable civilian curtailment in certain areas; and that if the war should continue into 1945 and 1946, provision would unquestionably have to be made for still further expansion of the defense effort.

"Now," he added, "we are at war and cannot wait until 1945 or 1946 for a program involving war expenditures at the rate of 50 to 60 billion dollars a year. We face annual energy requirements of about 150 billion kilowatt-hours for the war program."

Asserting that multiplication of steam generating capacity, as the war efforts progress, would involve increasing problems of fuel supply, Mr. Olds took occasion to urge construction of the St. Lawrence and other proposed Federal hydro projects which he believed could be constructed in a time comparable with equivalent steam capacity, in view of present labor and priority conditions. He also urged further power planning based on development of regional resources to permit industrial development in new areas, and took occasion again to criticize the viewpoint expressed some time ago by C. W. Kellogg of the Edison Electric Institute as to the adequacy of central station capacity.

Prevention of Fuel Waste

Estimating the probable preventable fuel loss this year as thirty-five million tons of coal, **V. G. Leach**[1] placed the blame on the vast number of small plants, the majority of which lack proper repair, maintenance and checking of operation. He observed that among the larger industrial plants conditions are immeasurably better although perhaps from 10 to 30 per cent require some attention. He absolved the central stations, however, from contributing to such loss.

During the depression years many of these small plants were neglected and in most cases no money was spent that could be avoided. Breakdowns alone were responsible for much of the maintenance and repair expense and it was only because of light loads or the skill of some of the "old school" engineers that these plants were enabled to "get by." However, many of these operators were replaced by lower salaried and less experienced men and today the problem of securing competent operators for these smaller plants is a serious one.

Happily, however, the increasing use of the small stoker offers one means of preventing fuel waste. More than a third of a million were installed in the past two years—116 times as many as in 1929 and 1930.

Speaking for the coal industry, Mr. Leach stated that it is now engaged in studying the problem through intelligent engineering analysis and extensive research, and that the coal screening plants are being changed into highly organized coal refineries to produce special grades and sizes of coal particularly suited to meet increased steam demands on both modern and old equipment. A salient feature of the coal refining process is the elimination of approximately one-third of the ash content of the coal, which represents a substantial saving not only in railway haulage but also means increased plant capacities and lowered maintenance.

Maximum Output From Existing Boiler Plants

E. G. Bailey[2] expressed the opinion that stations now operating will be called upon to supply most of the

[1] Chief Combustion Engineer, Peabody Coal Company.
[2] Vice President, Babcock & Wilcox Company.

power needed to see us through the war, inasmuch as steel and other metals are more urgently needed for ships, fighting equipment, new oil refineries, etc. Hence, power plants which formerly operated with comfortable capacity factors will be stepped up close to the 100 per cent mark. This will necessitate intelligent inspection, repair and maintenance, for nothing decreases output so seriously as emergency or unscheduled outage. Citing tube failures and leaks as the most frequent cause of forced boiler outages, he listed scale due to improper feedwater treatment, faulty circulation, priming and carryover, thermal stresses, corrosion, cutting of tubes by soot blowers, and low water as the principal contributing factors.

Although progress in feedwater treatment has been very real, there are still more outages due to tube losses from boilers than from any other one cause. With the urge to keep boilers operating at higher outputs and for longer periods between scheduled outages for inspection and cleaning, forced outages due to inadequate feedwater treatment are likely to increase.

There has been and still is some faulty or inadequate circulation in some types of boilers and some arrangements of water walls, but the later units of all manufacturers are nearly, if not entirely free from this fault, as experience has been effective in improving design. "Circulation has often been erroneously accused of tube losses that were due to scale or sludge," said Mr. Bailey, "and it is now believed that many changes made to amplify circulation were unjustifiably demanded by operators." However, there are boilers, mostly of the older vintage in operation today, which may have limitations in circulation such as to prevent an increase in output beyond a certain point; and the manufacturer should be consulted about increasing the output of such boilers.

While not of general extent in many plants, there have been some very serious outages and losses in output due to corrosion and tube wastage. Although internal corrosion may at first be considered a simple problem of feedwater treatment, it may be more insidious and serious than that. The presence of copper or other unusual factors may be contributing causes, and there are still some plants that do not employ proper deaeration with the result that corrosion or pitting takes place. External wastage has been encountered in a few furnace wall tubes during the past seven or eight years, but more recently it has taken place to a serious degree. Although the entire cause and remedy have not yet been found, the wastage appears to occur in zones in proximity to flame where there is almost complete absence of oxygen in the furnace's gases. Higher outputs and scale or sludge in the tubes seem to accelerate such external wastage.

The second half of Mr. Bailey's paper dealt with fuel-burning factors that may be responsible for reduction in output where changes in fuel become necessary as a result of war conditions. In this connection he made suggestions as to procedures that would avoid furnace explosions, assure maximum output and minimum maintenance of pulverizers and stokers, and successfully handle the problem of ash and clinkers.

Without going into details, Mr. Bailey stated that furnace explosions cannot occur upon lighting if

(1) the furnace is purged of all fuel;
(2) ample torch flame is properly applied to each burner before fuel is turned on to each burner in succession;
(3) air velocity at each burner is kept low enough to prevent blowing out the flame;
(4) fuel is supplied in a sufficiently rich mixture to immediately ignite from the torch;
(5) after ignition is established, the correct proportion of fuel and air is maintained through the entire time the furnace is in operation, and if the furnace is operated at a high enough rate to maintain stable ignition.

Forced-Circulation Boiler

At last year's Conference, **F. H. Rosencrants**[3] gave an informal talk reviewing briefly some of the design features of the C-E Controlled Forced-Circulation steam generating unit then on order for the Somerset Station of the Montaup Electric Company. In the interim, the unit has been delivered, erected and undergone a hydrostatic test, and is scheduled for operation the latter part of this month. The talk at this year's meeting dealt largely with construction features.

Although, in principle, the chief differences between this unit and one employing natural circulation are the employment of circulating pumps and calibrated orifices in the lower header system to control the flow to each circuit, yet in detail many departures from normal boiler construction are involved. These details were discussed and illustrated by slides selected from a large number of pictures taken during erection.

To recapitulate briefly, the unit is rated at 650,000 lb of steam per hour at an operating pressure of 1625 lb at the superheater outlet and 960 F total steam temperature. It is tangentially fired with pulverized coal from the existing storage system, has provision for firing with oil as an auxiliary fuel, and employs a slagging bottom furnace. The high-pressure steam will be supplied to a 25,000-kw topping turbine generator and exhausted at approximately 400 lb, through a reheater, to low-pressure turbine units. In all, steam from the high-pressure boiler will account for a total of 72,800 kw and will be produced in a space that was originally laid out for one-third this capacity. Some additional low-pressure capacity is supplied by existing 400-lb boilers.

Except for the convection surface represented by the two-stage superheater, the reheater and the economizer, all the heat-absorbing surface is radiant, the furnace tubes being plain 1¼ in., closely spaced and bifurcated into 1½-in. tubes entering the headers. No rolled joints are employed in the high-pressure parts, there being 2640 field welds in the more than 22 miles of tubing constituting the furnace walls, superheater, economizer and miscellaneous connections. Some of these welding operations were shown by the slides, as were also the header system with its control orifices, and other parts.

Employment of small tubes for this high pressure makes for less weight, thinner walls with a consequent reduction in temperature gradient and reduced stresses, and assures a high velocity with a high degree of turbu-

[3] Vice President, Combustion Engineering Company, Inc.

lence. The following comparison was offered between 1¼-in. tubes with forced circulation and 3-in. tubes for natural circulation and a similar furnace under like steam conditions.

	Forced Circulation 1¼-In. Bifurcated	Natural Circulation 3-In. Bifurcated	3-In. Finned
Weight of pressure parts (exclusive of superheater and economizer)	1	1.36	1.17
Weight of furnace tubes only	1	2.10	1.56
Water in furnace only	1	2.74	1.77
Water in circulation (exclusive of that in economizer)	1	1.53	1.26
Thermal capacity of water and metal (exclusive of superheater and economizer)	1	1.46	1.23

With reference to the circulating pumps of which there are three (two for normal operation and one spare), these operate at a differential pressure of 40 to 50 lb which is sufficient to overcome the resistance of the circuits and the drop through the orifices. The water handled by these pumps (which are distinct from the boiler-feed pumps) is several times the steam production rate of the unit and independent of the load. Therefore, wetted surfaces are assured at all points where gas comes in contact with the tubes. The positive circulation permits wide latitude in the arrangement of the heat-absorbing surfaces and in the location of the drum to suit local space requirements. This, incidentally, offers a special advantage in marine installations where limited headroom may not afford sufficient hydraulic head with high steam pressure and natural circulation.

Mr. Rosencrants pointed out that the time for complete circulation of the water in the system with two pumps running is approximately one minute. This rapid circulation should maintain a uniform distribution of any feedwater treatment that may be found necessary, and any boiler water sample may be regarded as representative of that in all parts of the system. The power input for the circulating pumps is estimated at about 0.3 per cent of the total output of the unit. Furthermore, as the circulating pumps will always be started before the fires are lighted, the establishment of circulation is not dependent upon the application of heat; hence quick starting is possible.

Results With Large Spreader Stoker

R. N. Bucks[4] related how The Studebaker Corporation, early in 1940, had been faced with the need for 175,000 lb per hr of additional steam continuously and four-hour peaks of 210,000 lb for heating enameling ovens. Only a limited space 24 ft wide and 16 ft 8 in. deep was available in the existing boiler room for the installation of a new steam generating unit, and a further condition was that it be capable of burning any available coal, particularly low-grade Indiana and Illinois screenings. Thus, with only about 400 sq ft of grate surface available, it would be necessary to burn 50 lb of coal per square foot per hour to meet the continuous load and 65 lb to carry the peaks.

To meet these conditions, a Detroit spreader stoker having six overthrow coal feeding units and a continuous ash discharge was selected, despite the fact that it would be twice the size of any stoker of this type then in actual operation. A three-drum Foster Wheeler boiler was purchased and set with the center of the mud drum 21 ft above the firing floor, so as to provide a distance of 30 ft of flame travel to the tube bank. The furnace volume is 9700 cu ft, and the heat release 29,100 Btu per cu ft at peak load. Water walls and an economizer are provided and the operating steam conditions are 250 lb pressure, 520 F total steam temperature.

For the year 1941 the average efficiency of the unit, including standby losses, corrected for blow-down, and covering a load range from 35,000 to 225,000 lb per hr, was 82.4 per cent. The monthly efficiency varied from 80.5 to 84.4 per cent. During this time coal costing on the average of $3.25 per ton and coming from six different mines in Illinois and Indiana was burned. It had the following average analysis:

Volatile	36 per cent
Carbon	40 per cent
Sulphur	4 per cent
Ash	14 per cent
Moisture	10 per cent
Ash fusion point	2000 F
Btu per lb, as fired	11,000

A few car loads of 14,000 Btu West Virginia coal were burned just to see how it would work and it performed splendidly. This was 1¼-in. × 0 raw screenings or smaller sizings. No prepared sizes of washed or dedusted coal have been used.

An average of 14.5 per cent CO_2 was maintained in the furnace and the steam cost figured 18.7 cents per 1000 lb. Maintenance was practically nil.

The author reported that the cinder-separating fan was effective in keeping to a minimum the fly ash accumulation in the stack base and preventing objectional discharge from the stack. Moreover, no slagging of the boiler tubes was encountered, even though coal with a sulphur content as high as 5.6 per cent was burned at times.

In concluding, the author observed that the spreader stoker offered a solution to the problem of burning such coal as might be available due to war conditions.

Water Problems in Small Power Plants

While the term "small plant" is relative and thus hard to define, **E. P. Partridge**[5] and **A. L. Soderberg,**[6] in their paper under the above title, classified the small plant as one in which the management regards the production of power and process steam as a necessary nuisance. Such plants are certain to have their share of water problems, chief of which are the keeping of heat-transfer surfaces from overheating by the prevention of scale, and the prevention of corrosion due to oxygen.

Formerly, the almost universal cause of overheating was scale, formed as a hard, compact, insulating layer of calcium sulphate or carbonate, or silicate on the heat-transfer surfaces; but with the application of scientific water conditioning, no plant today need be troubled by such scales.

However, many small plants have not deemed it necessary to go to this limit, involving usually primary external treatment followed by full internal conditioning with phosphate. For instance, many low-pressure plants in the Middle West have been accustomed to

[4] Superintendent of Power Plants, The Studebaker Corporation.

[5] Director of Research, Hall Laboratories, Inc., Pittsburgh.
[6] Engineering Service, Hall Laboratories, Inc., Chicago.

treat their water with a relatively small amount of sodium carbonate or caustic soda so as to precipitate calcium carbonate as a heavy sludge in the boiler. Despite the use of organic dispersing agents, trouble has been experienced with deposits in feedwater heaters and feed lines, but with cleaning every two or three weeks, boiler tubes have not accumulated enough scale to cause tube failures at moderate rates of heat input.

Today, however, with capacity as the criterion in many such plants, involving higher rates of heat input, calcium carbonate scale will develop in spite of soda-ash treatment. Therefore, unless more advanced water conditioning is employed, the engineer will be faced with the choice of taking the boiler off the line for more frequent cleanings, or having it come off at some particularly inconvenient moment with a ruptured tube.

With a typical midwestern water, high in calcium and carbonate ions, lime-soda softening has the advantage of reducing both the dissolved solids in the boiler water and the carbon dioxide in the steam at the same time it precipitates outside of the boiler the calcium carbonate sludge that otherwise would have to be removed by blowdown and mechanical cleaning. However, even the best softening will not prevent the formation of calcium carbonate scale on hard-worked heat-transfer surfaces when the water is evaporated in the boiler. By using a second stage of softening in which sodium phosphate is added, the amount of calcium ion left in the feedwater may be still further reduced by its removal as calcium phosphate. Here subsequent treatment with acid is desirable to prevent accumulation of this substance in the lines between the softener and the boiler.

Base-exchange treatment will accomplish the same general results as lime-soda softening and can be operated to yield a water containing even lower residual concentrations of calcium and magnesium ions. Base-exchange on the sodium cycle alone, however, is disadvantageous with a water high in bicarbonate, since it leads to high blowdown and also allows most of the carbon dioxide to be liberated in the steam.

An economic balance usually favors lime-soda for waters high in hardness and base exchange, on the combined hydrogen and sodium cycles for those low in hardness. In the current emergency, however, it is probable that hard pressed boilers operating at pressures below 200 lb can be kept on the line month after month if all the calcium ion entering in the feedwater is precipitated as calcium phosphate sludge.

The authors devoted the remainder of their paper to a discussion of steam blanketing, the instability of boiler steel, physical factors in the oxidation of steel by water, the chemical acceleration of oxidation, and intergranular damage to boiler steel.

Natural Circulation Problems

In stressing the fact that natural-circulation boilers will be given increasing competition by forced-circulation boilers, **A. A. Markson**[7] outlined fundamental problems which are critical in determining the economics of steam generation. These were: (1) What heat transfer laws govern the flow of heat to steam and water mixtures in boiler tubes in either forced or natural circulation? (2) Under what conditions do tubes get into trouble through steam blanketing or other circulation failure? (3) How may nature's provision for circulation be compared with nature's requirements on heat transfer? (4) Information on friction factors in tubes carrying varying mixtures of steam and water. (5) Knowledge of known and useful experimental methods. The objective of the paper was to incite others to further research and to put data and theory advanced to the test.

After reviewing the variable factors affecting transfer, it was stated that the heat transfer between the metal and the fluid is a related function of the mass flow in the tube, the latent heat, and the rate at which heat is applied. Reference was made to experiments at Sherman Creek and Kips Bay and to experiments run on liquid heating where no evaporation took place, and the findings were sufficiently concordant to be summarized in an equation expressing a dimensionless parameter φ. Against φ was plotted the overall coefficient of heat transfer Uo, and two effects were observed: (*a*) Uo for the larger coils varied according to pressures, and (*b*) Uo is (up to a value of φ about 10) just about proportional to the metal thickness. Above 10 there is a falling off of Uo for pressures below 2800. Up to this value Uo was remarkably constant over a wide range of φ. For a tube having uniformly distributed heating φ is equal to a geometric constant times the outlet quality. For pressures above 2800 the coefficients seem to follow the laws of convective heat transfer.

Among other papers on the program was one by **A. R. Ulstrom** on "Power in the Flour Milling Industry" which traced the application of water power in combination with steam power during the last eighty or ninety years in the flour mills at Minneapolis, and discussed the more recent applications of electric drive in which the synchronous motor now plays an important role.

Two sessions were devoted to electric power transmission, the first having two papers on lightning; and the second, a symposium on "Recent Developments in the Prevention of Outages on Transmission Systems."

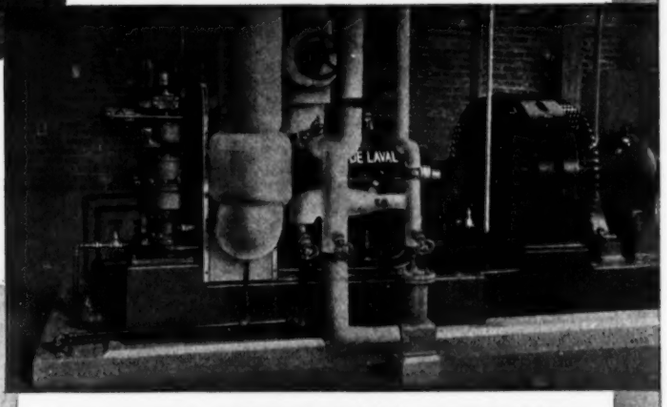
There was also a session on internal combustion engines which included a paper on "Diesel vs. Steam Locomotives" by Robert Aldag, of the Chicago, Burlington and Quincy Railroad, and another on "Production Testing of Aircraft Engines" by C. A. Chayne, Chief Engineer of the Buick Motor Division.

At the Luncheon Meeting on Tuesday, O. K. Jelinek, Chief of Techniques, Chicago Metropolitan Area, discussed blackouts and bombings with particular reference to the defense organization that has been created for the protection of Chicago. In this connection, various techniques are being worked out in the laboratory and tested by means of scale models, both of the dioramic and panoramic types, and then tested in the field at different elevations.

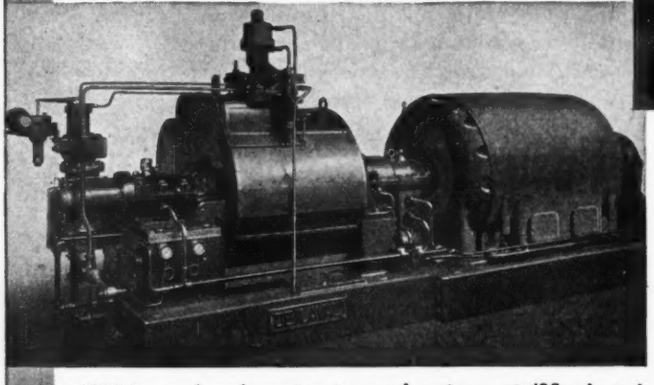
The "All Engineers Dinner" on Thursday evening was well attended. William F. Sims, of the Commonwealth Edison Company, acted as toastmaster and the speaker was Willard Chevalier, Vice President of McGraw-Hill Publishing Company, whose topic was "Business Looks at the War."

[7] Hagan Corporation, Pittsburgh.

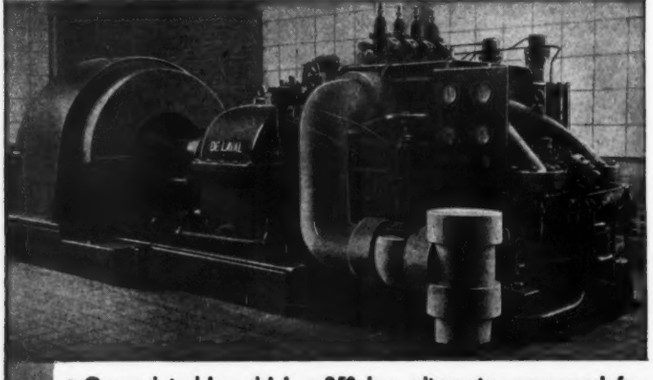
DE LAVAL
TURBO-ALTERNATORS
of small and medium capacities



- De Laval 4000 kw. (5000 kw. maximum) turbo-alternator; operates on steam at 425 psi. and 720° F., exhausting to condenser, with extraction at three points for heating buildings and feed water. A similar De Laval unit rated at 6000 kw. has since been ordered.
- Geared turbine driving 170 kw. alternator, back pressure service.



- 1000 kw. turbo-alternator, to receive steam at 425 psi. and 600° F. and to exhaust to process against 95 psi. gage.



- Geared turbine driving 850 kw. alternator arranged for extraction and condensing service.

DE LAVAL MULTISTAGE TURBINES

in modern designs, using the best improved alloys to withstand high pressure, high temperature steam, are available in capacities up to 15,000 hp. In medium and larger capacities they can be directly connected to alternators, while in smaller capacities or for driving D.C. generators a De Laval double helical speed reducing gear makes possible maximum efficiency by using ideal turbine speeds.

De Laval turbines are of the impulse type, with ample bucket clearances and with provisions to equalize expansion and permit of quick starting. Segregation of moisture in the low pressure stages increases efficiency and reduces erosion.

For further particulars, see Publication T-3522.

DE LAVAL *Steam Turbine Co.*
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MANUFACTURERS OF TURBINES, STEAM, HYDRAULIC, PUMPS, CENTRIFUGAL, PROPELLER, ROTARY, DISPLACEMENT, MOTOR-MOUNTED, MIXED-FLOW, CLOGLESS, SELF-PRIMING, CENTRIFUGAL BLOWERS and COMPRESSORS; GEARS, WORM, HELICAL and FLEXIBLE COUPLINGS

Combustion Calculations by Graphical Methods— U. S. COALS

This is the fifth of a series of articles by the author, each dealing with a particular fuel. By the use of charts combustion calculations can be quickly and accurately made. The first, which appeared in the August issue, dealt with fuel oil; the second, in October, with coke-oven gas; the third, in December, with blast-furnace gas; and the fourth, in February, with natural gas. The next article, scheduled for June, will take up coke.

By A. L. NICOLAI
Combustion Engineering Co., Inc.

COAL is a solid fuel that is commonly believed to be the result of gradual decomposition of vegetable matter over long periods of time. It contains the same elements as wood, leaves and other vegetation, but in different proportions. These organic substances are chiefly made up of carbon, C, hydrogen, H_2, oxygen, O_2, nitrogen, N_2, ash and moisture. Under high pressure and temperature, the less stable hydrogen and oxygen in the vegetable matter combine with some carbon to form carbon dioxide and hydrocarbons which, being volatile, escape to the atmosphere. Most of the carbon, on the other hand, being more stable remains in a solid state to form the principal component of coal. Thus, an increase in geologic time is accompanied by a corresponding increase in the carbon content of the coal over that present in organic matter.

Coal is comparatively abundant in nature but, since both its physical and chemical properties vary considerably, it is grouped into various classes. The broadest classification, and the most commonly spoken of, divides all coals into (1) anthracite, (2) bituminous and (3) lignite. In point of time, anthracite is geologically the oldest, whereas lignite is the most recent.

Anthracite comprises a variety of slow-burning fuels merging into graphite at one end and into bituminous coal at the other. They are the hardest coals on the market, consisting almost entirely of fixed carbon, with the little volatile matter present in them chiefly as methane, CH_4. Anthracite is usually graded into small sizes before being burned on stokers: the "super-anthracites" burn so slowly as to require mixing with other coals, while the "semi-anthracites," which have more volatile, are burned with relative ease if properly fired.

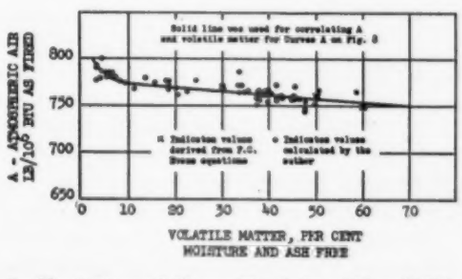

Fig. 1—Variation of theoretical air with volatile matter

Bituminous coals form by far the largest group and derive their name from the fact that on being heated they are often reduced to a cohesive, binding, sticky mass. Their carbon content is less than that of anthracites, but they have more volatile matter. The character of their volatile matter is more complex than that of anthracites, but higher in calorific value. They burn easily, especially in pulverized form, and their high volatile content makes them good for producing gas. Their binding nature enables them to be used in the manufacture of coke, while the nitrogen in them is utilized in processing ammonia.

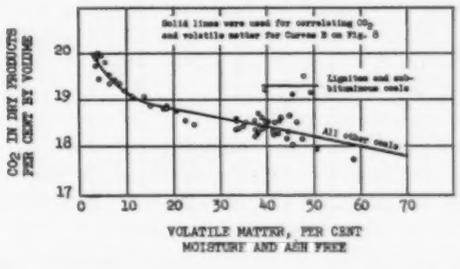

Fig. 2—Variation of theoretical CO_2 with volatile matter

Lignites are the last of the broad classification of coals and the nearest in composition and physical appearance to wood (the word "lignite" comes from the Latin word "lignum" meaning wood). Their origin is mostly from plants rich in resin, while their color is brown or black. They contain a large amount of volatile matter, which instead of consisting of hydrocarbons is largely made up of non-combustible CO_2.[1] This accounts for the discrepancy that is evident in Fig. 2 when an attempt is made to relate the volatile matter of all coals to the per cent CO_2 in their products of combustion. Lignites are also characterized by their high moisture of crystallization, which on heating causes them to crumble and sift through stoker grates.

[1] "Engineering Thermodynamics," by C. E. Lucke.

The classification just described is not definite enough to be of real use. Further grouping into "ranks" was therefore found necessary, and this was accomplished by a study of the proximate analyses and heating values of the different fuels. Thus, anthracite was subdivided into super-anthracites, anthracites and semi-anthracites; bituminous coals became low-volatile bituminous, medium-volatile bituminous, high-volatile bituminous A, high-volatile bituminous B, high-volatile bituminous C and sub-bituminous coals; and, lastly, came the lignites. Fig. 5, which is a revision by the author of M. R. Campbell's original diagram,[2] shows about what proximate analysis may be expected with each rank, while Table 1 lists the range in proximate analyses of typical U. S. coals.

Proximate Analysis

The classification of coals was made easier by development of the method of "proximate analysis," which consists in determining the moisture, volatile matter, fixed carbon and ash of a given coal sample, by weight. The moisture content is obtained by noting the loss of weight in the sample when it is heated at a temperature of about 220 F for an hour. The moisture thus determined includes surface as well as inherent or hygroscopic moisture. The volatile matter is the loss in weight which follows additional heating of the sample to a temperature of about 1750 F for a half-hour, with all air excluded. The fixed carbon is calculated from the further reduction in weight of the sample which takes place when the coal is completely burned in the presence of air, while the ash is the residue at the end of complete combustion.

This method of analyzing coals is simple and quick, and, therefore, favored by many engineers. However, as it is approximate in nature, it is well to remember that combustion calculations which are based on it may be considerably in error. For example, it is necessary to know the hydrogen in the coal in order to evaluate the moisture loss in a heat balance. On Fig. 7 are drawn three curves, taken from DeBaufre's original correlation,[3] which relate the percentage of volatile matter in the proximate analysis to the percentage of hydrogen in the fuel. Actual values of hydrogen for certain coals will be found to differ from these average curves by as much as 1.7 per cent. This represents a variation of 12 lb per million Btu in the water formed by combustion of the hydrogen, which means that the moisture loss estimated from a proximate analysis may be 1.5 per cent greater or smaller than it should be, if such loss is based on 500 F. This discrepancy alone may, then, be sufficient to absorb the entire unaccounted-for loss of 1.5 per cent, which it is customary to set up in a heat balance as a margin of safety.

It has already been mentioned that the character of the volatile matter is not the same for all coals, because some of them have more carbon dioxide in them than others. This fact accounts for the two distinct groups of points occurring on Fig. 2, which is a correlation of the per cent CO_2 in the dry products of combustion with the volatile matter in the proximate analysis. Thus it is that lignites and sub-bituminous coals form on the average about one per cent more CO_2 than bituminous coals of the same volatile content. The kind of hydrocarbon in the volatile has also a direct bearing on the position of the point in Fig. 2 since different hydrocarbons generate different amounts of carbon dioxide. Plotting the per cent CO_2 against the ratio of fixed carbon to volatile matter, as some engineers have suggested to the author, does not line up the points any better.

Ultimate Analysis

From the foregoing discussion, it is obvious that for accurate combustion calculations it is preferable to have an ultimate analysis of the coal. A complete ultimate analysis of coal on the "as-fired" basis includes moisture,

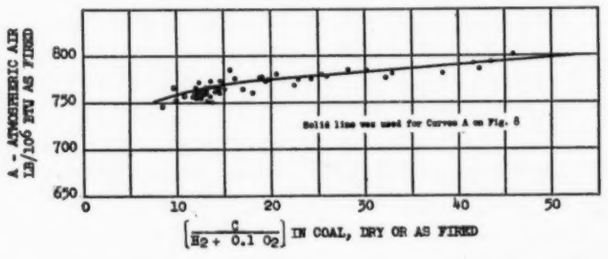

Fig. 3—Variation of theoretical air with $\left[\frac{C}{H_2 + 0.1\ O_2}\right]$

H_2O, carbon, C, hydrogen, H_2, sulphur, S, oxygen, O_2, nitrogen, N_2 and ash reported in per cent by weight. The moisture and ash determination is the same as for the proximate analysis, whereas all other elements but oxygen are obtained by the test procedure described in the A.S.T.M. "Standards on Coal and Coke." The amount of oxygen is estimated by subtracting the sum of the percentages of the other constituents from 100. Sometimes, instead of being reported as a separate item, the moisture in the ultimate analysis is divided into eight parts oxygen and one part hydrogen which are then added to the oxygen and hydrogen of the combustible in the coal. For combustion calculations, this is not a good practice because in computing a heat balance the surface and inherent moisture in the fuel requires a different treatment from the water formed in burning hydrogen.

Since an ultimate analysis includes the per cent hydrogen, no difficulty is experienced in calculating accurately the water formed by burning it. Furthermore, by knowing the ultimate analysis, it is possible to obtain a much better correlation between the per cent CO_2 in the dry products of combustion and the simple ratio $\left[\frac{C}{H_2 - 0.1\ O_2}\right]$ for all coals, including lignite and sub-bituminous. This is shown by Fig. 4 where it is seen that no CO_2 value plotted deviates from the solid line used in labeling curves *B* of Fig. 8 by more than 0.30 per cent. These are the principal reasons for the author's preference for the ultimate over the proximate analysis.

In the first of this series of articles on "Combustion Calculations by Graphical Methods,"[4] it was pointed out that Rosencrants, de Lorenzi and Marshall had published charts for coal of the same general character as those presented by the author. However, these earlier charts were only applicable to a restricted number of bituminous coals and could not be used for anthracite, lignite or high-oxygen bituminous coals without considerable error. On Fig. 1 is shown the variation of the "atmospheric" air

[3] A.S.M.E. *Transactions*, 1927–28.
COMBUSTION, May 1931.

[4] COMBUSTION, August 1941.

TABLE 1 - ANALYSES OF TYPICAL U. S. COALS, AS MINED

No.	STATE	RANK	Proximate Analysis Per Cent: Moisture	Vol. Matter	Fixed Carbon	Ash	Ultimate Analysis Per Cent: Moisture, H_2O	Carbon, C	Hydrogen, H_2	Sulphur, S	Oxygen O_2	Nitrogen, N_2	Ash	Heating Value Btu per lb: High	Low	Atmos. Air at zero excess air, lb/10⁶Btu	CO_2 at zero excess air, per cent
1	R.I.	Super-Anth.	13.3	2.5	65.3	18.9	13.3	64.2	0.4	0.3	2.7	0.2	18.9	9313	9126		
2	Colo.	Anthracite	2.5	5.7	83.8	8.0	2.5	83.9	2.9	0.7	0.7	1.3	8.0	13720	13410	785	19.3
3	N.Mex.	"	2.9	5.5	82.7	8.9	2.9	82.3	2.6	0.8	1.3	1.2	8.9	13340	13055	783	19.5
4	Penn! Orch.Bed	"	5.4	3.8	77.1	13.7	5.4	76.1	1.8	0.6	1.8	0.6	13.7	11950	11715	781	20.0
5	Mamm.Bed	"	2.3	3.1	87.7	6.9	2.3	86.7	1.9	0.5	0.9	0.8	6.9	13540	13329	793	20.0
6	Holmes*	"	4.9	3.7	82.2	9.2	4.9	81.6	1.8	0.5	1.3	0.7	9.2	12820	12591	787	20.0
7	Arkansas	Semi-Anth.	2.1	9.8	78.8	9.3	2.1	80.3	3.4	1.7	1.7	1.5	9.3	13700	13447	768	19.1
8	Penn.	" "	3.0	8.4	78.9	9.7	3.0	80.2	3.3	0.7	2.0	1.1	9.7	13450	13096	774	19.2
9	Virginia	" "	3.1	10.6	66.7	19.6	3.1	70.5	3.2	0.6	2.2	0.8	19.6	11850	11505	782	19.1
10	Arkansas	Low-Vol.Bit.	3.4	16.2	71.8	8.6	3.4	79.6	3.9	1.0	1.8	1.7	8.6	13700	13383	773	18.8
11	Maryland	" " "	3.2	18.2	70.4	8.2	3.2	79.0	4.1	1.0	2.9	1.6	8.2	13870	13436	762	18.7
12	Oklahoma	" " "	2.6	16.5	72.2	8.7	2.6	80.1	4.0	1.0	1.9	1.7	8.7	13800	13382	776	18.8
13	Penn.	" " "	3.3	20.5	70.0	6.2	3.3	80.7	4.5	1.8	2.4	1.1	6.2	14310	13836	765	18.5
14	W.Va.	" " "	2.7	17.2	76.1	4.0	2.7	84.7	4.3	0.6	2.2	1.5	4.0	14730	14282	767	18.9
15	Virginia	Med.-Vol.Bit.	3.1	21.8	67.9	7.2	3.1	80.1	4.7	1.0	2.4	1.5	7.2	14030	13539	777	18.5
16	Alabama	High-Vol.Bit.A	5.5	30.8	60.9	2.8	5.5	80.3	4.9	0.6	4.2	1.7	2.8	14210	13673	765	18.6
17	Colo.	" " " "	1.4	32.6	54.3	11.7	1.4	73.4	5.1	0.6	6.5	1.5	11.7	13310	12898	765	18.4
18	Kansas	" " " "	7.4	31.8	52.4	8.4	7.4	70.7	4.6	2.6	5.0	1.3	8.4	12670	12141	767	18.3
19	Kentucky	" " " "	3.1	35.0	58.9	3.0	3.1	79.2	5.4	0.6	7.2	1.5	3.0	14290	13731	758	18.5
20	Missouri	" " " "	5.4	32.1	53.5	9.0	5.4	71.6	4.8	3.6	4.2	1.4	9.0	12990	12463	751	18.2
21	New Mex.	" " " "	2.0	33.5	50.6	13.9	2.0	70.6	4.8	1.3	6.2	1.2	13.9	12650	12161	766	18.4
22	Ohio	" " " "	4.9	36.6	51.2	7.3	4.9	71.9	4.9	2.6	7.0	1.4	7.3	12990	12460	759	18.2
23	Oklahoma	" " " "	2.1	35.0	57.0	5.9	2.1	76.7	4.9	0.5	7.9	2.0	5.9	13630	13131	767	18.7
24	Penn.	" " " "	2.6	30.0	58.3	9.1	2.6	76.6	4.9	1.3	3.9	1.6	9.1	13610	13105	773	18.4
25	Tenn.	" " " "	1.8	35.9	56.1	6.2	1.8	77.7	5.2	1.2	6.0	1.9	6.2	13890	13365	767	18.4
26	Texas	" " " "	4.0	48.9	34.9	12.2	4.0	65.5	5.9	2.0	9.1	1.3	12.2	12230	11613	766	17.7
27	Utah	" " " "	4.3	37.2	51.8	6.7	4.3	72.2	5.1	1.1	9.0	1.6	6.7	12990	12446	757	18.5
28	Virginia	" " " "	2.2	36.0	58.0	3.8	2.2	80.6	5.5	0.7	5.9	1.3	3.8	14510	13952	762	18.3
29	Wash.	" " " "	4.3	37.7	47.1	10.9	4.3	68.9	5.4	0.5	8.5	1.5	10.9	12610	12037	760	18.2
30	W. Va.	" " " "	2.4	33.0	60.0	4.6	2.4	80.8	5.1	0.7	4.8	1.6	4.6	14350	13827	767	18.5
31	Illinois	High-Vol.Bit.B	8.0	33.0	50.6	8.4	8.0	68.7	4.5	1.2	7.6	1.6	8.4	12130	11604	767	18.5
32	Kentucky	" " " "	7.5	37.7	45.3	9.5	7.5	66.9	4.8	3.5	6.4	1.4	9.5	12080	11530	772	18.0
33	Missouri	" " " "	10.5	32.0	44.6	12.9	10.5	63.4	4.2	2.5	5.2	1.3	12.9	11300	10876	773	18.3
34	Ohio	" " " "	8.2	36.1	48.7	7.0	8.2	68.4	4.7	1.2	9.1	1.4	7.0	12160	11612	762	18.5
35	Wyoming	" " " "	5.1	40.5	49.8	4.6	5.1	78.0	5.0	0.5	10.6	1.2	4.6	12960	12417	756	18.7
36	Illinois	High-Vol.Bit.C	12.1	40.2	39.1	8.6	12.1	62.8	4.6	4.3	6.6	1.0	8.6	11480	10899	767	18.0
37	Indiana	" " " "	12.4	36.6	42.3	8.7	12.4	63.4	4.3	2.3	7.6	1.3	8.7	11420	10864	757	18.5
38	Iowa	" " " "	14.1	35.6	39.3	11.0	14.1	58.5	4.0	4.3	7.2	0.9	11.0	10720	10175	754	18.2
39	Michigan	" " " "	12.4	35.0	47.0	5.6	12.4	65.8	4.5	2.9	7.4	1.4	5.6	11860	11385	761	18.3
40	Colorado	Sub-Bitum.	19.6	30.5	45.9	4.0	19.6	58.8	3.8	0.3	12.2	1.3	4.0	10130	9544	756	19.2
41	Wyoming	"	23.2	33.3	39.7	3.8	23.2	54.6	3.8	0.4	13.2	1.0	3.8	9420	8794	757	19.1
42	No.Dak.	Lignite	34.8	28.2	30.8	6.2	34.8	42.4	2.8	0.7	12.4	0.7	6.2	7210	6552	747	19.5
43	Texas	"	33.7	29.3	29.7	7.3	33.7	42.5	3.1	0.5	12.1	0.8	7.3	7350	6675	752	19.2

at zero excess air with volatile matter on a "moisture and ash free" basis, while on Fig. 3 is indicated the change in atmospheric air with the ratio $\left[\frac{C}{H_2 + 0.1\ O_2}\right]$. Both Fig. 1 and Fig. 3 reveal that the maximum deviation in the calculated weight of air from the respective average curve is less than than $\pm$ 2.5 per cent.

In Table 1 are tabulated representative ultimate analyses of various ranks from different states in the Union. More extended lists are available in the various bulletins issued from time to time by the U. S. Bureau of Mines.

For purposes of reporting or correlation, laboratory technicians and investigators often find it convenient to express proximate and ultimate analyses on a basis other than "as fired." Thus, an analysis on the "as received" or "as sampled" basis serves to define the condition of the coal at the time it was tested. As "dry," the fuel is reported with the moisture item omitted; as "ash free," it is without ash, and as "moisture and ash free," it has had both moisture and ash eliminated from the analysis. However, as pointed out in previous articles on combustion calculations,[5] our chief concern is with the fuel "as fired" in the furnace.

[5] COMBUSTION, August, October, December 1941 and February 1942.

Heating Value

It is customary to report the high heating value of coal, in Btu per pound, along with the analysis, whether proximate or ultimate, and on the same basis as the analysis. The high heating value at constant volume can be accurately determined by burning a small sample of coal in a bomb calorimeter immersed in water, and measuring the temperature rise of the water.

Various formulas have been proposed for evaluating the Btu per pound of coal from its proximate or ultimate analysis. All of them yield only approximate results because they do not take into account the complex thermodynamic changes which occur when coal is burned.

If only the coal rank and its state of origin are known, it is best to assume the heating value from some reasonably close analysis in Table 1, or, if the ash percentage is known, the heating value may be judged from diagram *A* of Fig. 5. If a proximate analysis is available, Fig. 6, which is drawn from F. C. Evans' equations[6] may be used to estimate the heating value after converting the volatile matter to a "moisture and ash free" basis, but it should be noted that these equations do not apply to lignites or super-anthracites. The author, likewise,

[6] *Bulletin No. 3*, Engineering Experiment Station of Cornell University.

believes that it is good practice to check the heating value read from Fig. 6 against Table 1 for major discrepancies. When the ultimate analysis of a coal is given, its high heating value (*HHV*) in Btu per pound "as fired" may be found by Dulong's empirical formula,

$$HHV = 14{,}500\ C + 62{,}000\left(H_2 - \frac{O_2}{8}\right) + 4000\ S \qquad (20)$$

The fractions by weight of C, H$_2$, O$_2$ and S to be used in equation (20) should be on the "as fired" basis.

Dulong's formula will not give accurate heating values for sub-bituminous coals or lignites, the difference from

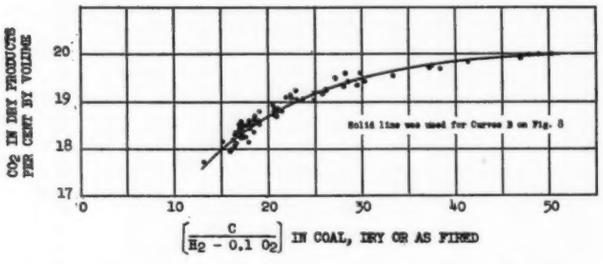

Fig. 4—Variation of theoretical CO_2 with $\left[\frac{C}{H_2 - 0.1\ O_2}\right]$

actual values amounting to as much as 4 per cent with sub-bituminous coals and 6 per cent with lignites, according to DeBaufre.

If the high heating value in Btu per pound, and the hydrogen and moisture fractions by weight "as fired" are known, the low heating value (*LHV*) at constant pressure, in Btu per pound as fired, may be computed from the following expression,[3]

$$LHV = HHV - 9720\ H_2 - 1110\ H_2O \qquad (21)$$

The low heating values listed in Table 1 were calculated by means of equation (21).

Combustible Loss

Combustible loss in coal-fired furnaces is the result of incomplete burning of either the solid or the volatile combustible in the fuel. The principal factors influencing the magnitude of this loss are the character of the coal itself, the method of firing it, and the furnace design and operation. With proper furnace design and operation, the loss due to unburned volatile, as determined by the presence of CO in the flue gas, is generally negligible. On the other hand, the loss due to solid combustible in the ash, as measured by the reduction in weight which a sample of ash refuse undergoes on being completely burned, may vary from a negligible amount in burning pulverized coal to 20 per cent of the coal fired, or more, with certain sizes of anthracite.

The combustible loss in the ash may be due to siftings through the grate openings in stokers, or to unburned fuel that is dropped into the ashpit from the end of the stoker. It may also be caused by combustible trapped in fly ash which is carried over from the furnace and deposited on boiler tubes, in soot hoppers, and on the landscape after going out through the stack, or in combustible that leaves with molten ash in tapping a slag-bottom furnace.

If K_1, K_2, etc., are known or assumed constants representing, respectively, the fractions of the total ash in a pound of coal which is deposited as siftings, in the ashpit, as fly ash, etc., W. S. Patterson has shown[7] that the total combustible loss may be expressed by the following equation,

$$\%\ \text{Solid combustible weight loss} = 100\left[\left(\frac{C_{R_1}K_1}{1 - C_{R_1}} + \frac{C_{R_2}K_2}{1 - C_{R_2}} \cdots\right) \times \text{ash in coal as fired}\right] \qquad (22)$$

where C_{R1}, C_{R2}, etc., are the respective weights of combustible per pound of dry refuse from siftings, ashpit, fly ash, etc. For a given coal burning unit the sum of all K's is, then, equal to one.

The results of equation (22) may be substituted in equation (3)[4]

$$C = 1 - \frac{\%\ \text{Solid combustible weight loss}}{100} \qquad (3)$$

to find the unburned combustible factor, C.

Fuel in Products, F.—Knowing the high heating value of the coal, its ash content, and its combustible loss factor C, that portion of the fuel which reappears in the products of combustion, F, is taken directly from Fig. 1 of the first article on combustion calculations.[4]

Atmospheric Air, A.—For any value of excess air up to 100 per cent, the atmospheric air in pounds per million Btu as fired may be taken from Curves *A*, Fig. 8, after determining either the ratio $\left[\frac{C}{H_2 + 0.1\ O_2}\right]$ from an ultimate analysis of the coal or the "moisture and ash free" volatile matter from a proximate analysis.

The empirical relation between A and $\left[\frac{C}{H_2 + 0.1\ O_2}\right]$

[7] COMBUSTION, February 1932.

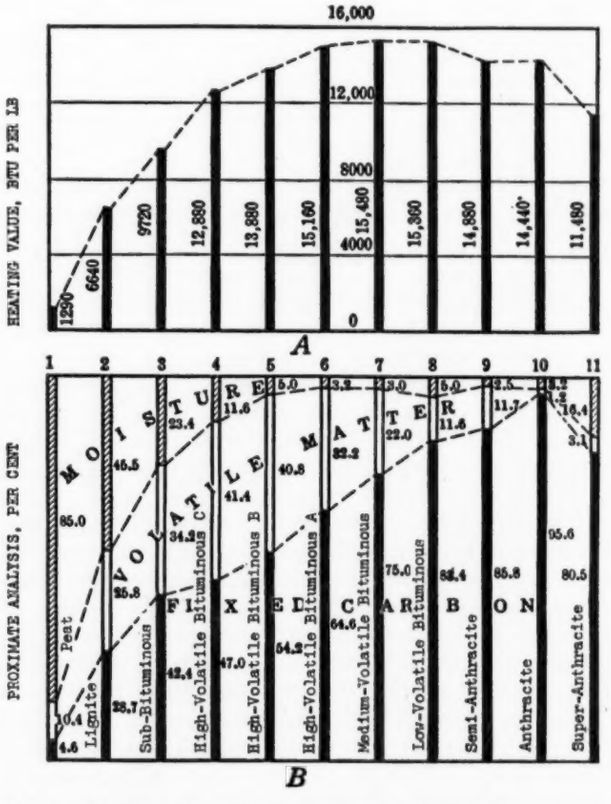

Fig. 5—Diagram showing progressive change from vegetable matter to coal. Proximate analyses and heating values are on the "ash free" basis

is shown by Fig. 3, while Fig. 1 indicates the trend of A with a change in the "moisture and ash free" volatile of the coal. On Fig. 1, the circles represent atmospheric air values calculated by the author from individual coal analyses, while the crosses are the result of a study of F. C. Evans' equations.[6]

Moisture in Fuel, W_f.—As already explained, the loss in weight caused by drying the coal at 220 F constitutes the total moisture reported in an analysis. To this moisture, when converted to pounds per million Btu, we already assigned the symbol W_c.[4] It is the sum of the surface moisture, which produces "wetness" in the coal, and the inherent or hygroscopic moisture, which being intimately held by the coal is not readily sensed. Table 1 reveals that in some high-volatile bituminous coals, the total moisture may be as low as 1.4 per cent, while it may go up to 34.8 per cent in lignite. The portion of W_c that is inherent moisture, likewise, varies from negligible amounts in super-anthracites to high values in lignites. Curves D of Fig. 8 offer a convenient method of obtaining W_c from the per cent moisture and high heating value of the coal as fired.

In addition to W_c, coal will yield water from burning of its hydrogen content. Curves C, Fig. 8, make it possible to determine this water, W_h, in pounds per million Btu, from the per cent hydrogen and high heating value of the coal as fired. If only a proximate analysis of the coal is available, its hydrogen content must first be read from Fig. 7. Special attention is called to the fact that whereas Curves C are based on hydrogen "as fired," the hydrogen from Fig. 7 is on a "moisture and ash free" basis, so that it must be converted to the "as fired" condition before entering on Curves C of Fig. 8.

W_f is the sum of W_c and W_h.

Per Cent CO_2 in Products.—The per cent CO_2 by volume in the dry products of combustion may be read from Curves B, Fig. 8, for excess air values up to 100 per cent of theoretical requirements and for $\left[\frac{C}{H_2 - 0.1\,O_2}\right]$ ratios from 12.5 to 50. The ratio $\left[\frac{C}{H_2 - 0.1\,O_2}\right]$ can, of course, be calculated from an ultimate analysis of the coal. In Fig. 4 is shown the relation between per cent CO_2 at zero excess air and $\left[\frac{C}{H_2 - 0.1\,O_2}\right]$ which was the basis for the CO_2 curves on Fig. 8.

When only a proximate analysis is given, the "moisture and ash free" volatile matter may be used to obtain the

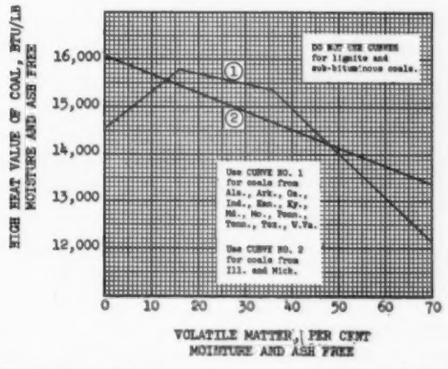
HIGH HEAT VALUE OF COAL, BTU/LB MOISTURE AND ASH FREE
16,000
15,000
14,000
13,000
12,000
DO NOT USE CURVES for lignite and sub-bituminous coals.
1
2
Use CURVE NO. 1 for coals from Ala., Ark., Ga., Ind., Kan., Ky., Md., Mo., Penn., Tenn., Tex., W.Va.
Use CURVE NO. 2 for coals from Ill. and Mich.
0 10 20 30 40 50 60 70
VOLATILE MATTER, PER CENT MOISTURE AND ASH FREE

Fig. 6—Variation of heat value of coal with volatile matter from F. C. Evans' equations

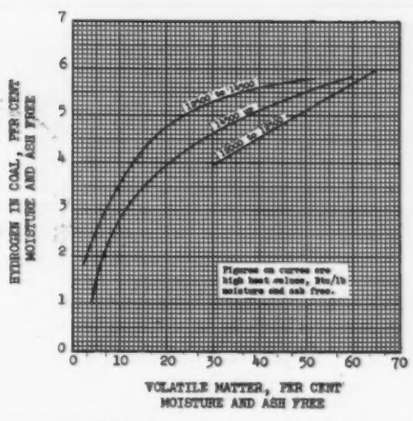

Fig. 7—Variation of hydrogen in coal with volatile matter from W. L. DeBaufre's correlation

CO_2 from Curves B for all but sub-bituminous coals and lignites. Because, as explained before, the volatile in the latter ranks does not possess the characteristics of other coals, the dotted line on Fig. 8 should be used when the ultimate analysis for sub-bituminous and lignitic coals is not available.

EXAMPLE

Assume that a Pennsylvania bituminous coal, having the typical proximate analysis of line 24, Table 1, is burned with 22 per cent excess air and that the expected solid combustible loss is 2 per cent by weight. Then

1. *Fuel, F.* The sum of the ash plus solid combustible loss is 9.1 + 2.0 = 11.1 per cent by weight. With this sum, and a high heating value from line 24, Table 2, of 13,610 Btu per lb, read from Fig. 1 of the August 1941 article in COMBUSTION F = 65 lb per million Btu.

2. *Atmospheric Air, A.* The sum of the ash plus moisture in the coal is 9.1 + 2.6 = 11.7 per cent, and the "moisture and ash free" volatile matter = $\left[\frac{30}{1 - \frac{11.7}{100}}\right]$ = 34 per cent. For this value of volatile matter and 22 per cent excess air, read from Curves A, Fig. 8, A = 935 lb per million Btu.

3. *Unburned Combustible Factor, C.* Since the solid combustible loss is 2 per cent, from equation (3),[4] we obtain $C = 1 - \frac{\%\text{ Solid combustible weight loss}}{100} = \left[1 - \frac{2}{100}\right] = 0.98$.

4. *Total Products, P.* From equation (4),[4] $P = F + CA$ = 65 + 0.98 × 935 = 981 lb per million Btu.

5. *Moisture in Air, W_a.* From equation (5),[4] $W_a = 0.013A$ = 0.013 × 935 = 12 lb per million Btu.

6. *Moisture From Fuel, W_f.* As explained before, W_f is the sum of W_c, the moisture in the coal as fired, and W_h, the water formed in combustion. From Curves D, Fig. 8, for 2.6 per cent moisture in the fuel and a high heating value of 13,610 Btu per lb, read W_c = 2 lb per million Btu.

Next, convert the high heating value "as fired" to a "moisture and ash free" basis, as follows: $\left[\frac{13{,}610}{1 - \frac{11.7}{100}}\right]$ = 15,400 Btu per lb, and use it, together with the "moisture and ash free" volatile determined for A, to read from Fig. 7 H_2 = 4.8 per cent "moisture and ash free," or reverting to the "as fired" basis, $4.8\left(1 - \frac{11.7}{100}\right)$ = 4.2 per cent hydrogen.

From Curves C, Fig. 8, for a high heating value of 13,610 Btu per lb and H_2 = 4.2 per cent, read W_h = 28 lb per million Btu.

$W_f = W_c + W_h = 2 + 28 = 30$ lb per million Btu

7. *Dry Gas, P_d.* From equation (7),[4] $P_d = P - (W_a + W_f)$ = 981 − (12 + 30) = 939 lb per million Btu.

8. *Per Cent CO_2 in Products.* For a "moisture and ash free" volatile matter of 34 per cent and 22 per cent excess air, read from Curves B, Fig. 8, CO_2 = 15 per cent.

(NOTE: Many of the foregoing figures will be somewhat different if the ultimate, instead of the proximate, analysis in line 24, Table 1, is used).

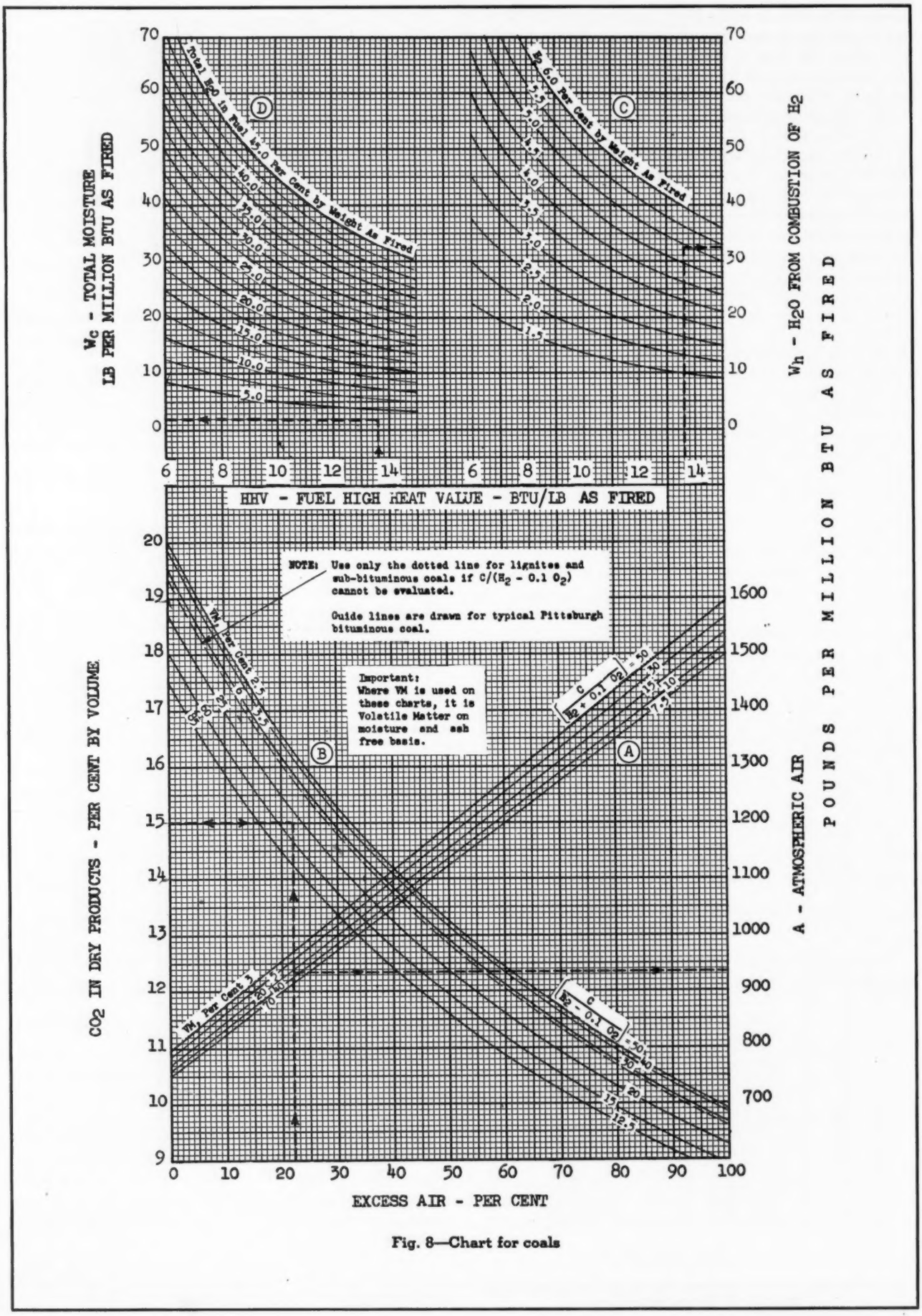
W_c - TOTAL MOISTURE
LB PER MILLION BTU AS FIRED
W_h - H_2O FROM COMBUSTION OF H_2
POUNDS PER MILLION BTU AS FIRED
A - ATMOSPHERIC AIR
CO_2 IN DRY PRODUCTS - PER CENT BY VOLUME
HHV - FUEL HIGH HEAT VALUE - BTU/LB AS FIRED
EXCESS AIR - PER CENT
Total H_2O in Fuel 45.0 Per Cent by Weight As Fired
H_2 6.0 Per Cent by Weight As Fired
NOTE: Use only the dotted line for lignites and sub-bituminous coals if $C/(H_2 - 0.1\ O_2)$ cannot be evaluated.
Guide lines are drawn for typical Pittsburgh bituminous coal.
Important: Where VM is used on these charts, it is Volatile Matter on moisture and ash free basis.
VM Per Cent
A
B
C
D

Fig. 8—Chart for coals

Automatic Control of Natural-Gas-Fired Power Boilers*

A review of some of the more common arrangements of control equipment to maintain constant steam pressure, sustain maximum combustion efficiency and promote safety in the burning of natural gas. Each of these points is discussed.

By CHARLES W. PARSONS
Republic Flow Meters Company

NATURAL gas is the principal fuel in the extensive oil-producing sections of the Southwest, and great pipe lines have also brought the many advantages of this fuel to numerous northern industrial areas. Whether the gas is burned in its natural condition as piped from the wells or in some mixture with manufactured or by-product gases, its efficient burning means dollars saved. This includes savings in gas cost, in increased pipe-line capacity to the plant, and in greater steam output from available boilers.

Although gas and other fuels can be burned efficiently under manual control, the advantages of dependable automatic control have been accepted by the designers and operators of most larger boilers, as well as many small boilers, throughout the gas-burning sections of the country. Constant steam pressure is essential for best turbine and engine performance and for precise processes, and highest efficiency of combustion is the goal in every boiler plant. Both are assured by properly designed and maintained automatic combustion control, regardless of sudden changes in load and burning conditions.

While such controls differ widely in design and arrangement each falls into one of several definite classifications according to arrangement. Almost every arrangement of such control equipment includes devices to accomplish three purposes:

1. Maintain constant steam pressure.
2. Insure most efficient burning of the gas.
3. Insure safety by preventing loss of ignition and similar hazardous conditions.

The prime mover of most power boiler control systems is a steam pressure measuring element connected to the plant steam header and designed to operate one or more valves to supply sufficient gas to the boiler furnaces to maintain that steam pressure constant. This element may operate a gas valve directly; it may actuate a regulator to control a gas valve; or it may be designed as a master steam element.

A master steam element converts a change in the steam pressure into a change in the master loading to the regulators or power valves which control the gas flow. It can include a compensator or automatic pressure reset, by which it will control for a definite steam pressure throughout the range of the firing equipment, regardless of the boiler characteristics. Where more than one boiler is involved a master controller can provide desirable flexibility of operation, as each boiler can be set to take any desired proportion of the total load. If the individual boiler manual control stations are provided as a part of this master, any boiler may be instantly placed on either manual or automatic control from this panel-mounted master station. Thus some boilers may be on manual control while others are automatically responding to steam pressure control.

The simplest control can use the master steam pressure element to advantage. A common arrangement is to master load the receiving regulators of the individual gas valves on each boiler. This permits use of a regulator with a positioning cam which can be given final field calibration to match the characteristics of the particular boiler and burners. Such regulators may also be pilot-valve actuated and power-cylinder operated and may have stabilizers and mechanical return-motion features, as the particular operation warrants.

This master loading pressure may also directly load a diaphragm-operated valve in the gas line to each individual boiler. Such diaphragm valves are of the positioning type. On smaller boilers similar diaphragm valves are used which have the steam-pressure element built into the valve to actuate a pilot valve admitting either air or gas pressure to the valve-operating diaphragm.

Certain manufacturers have developed a diaphragm- and pilot-operated valve which includes some advantages of the measured type of control, by making the valve sensitive to both the steam pressure being maintained and the gas pressure being supplied to the burners.

Other control systems use the opposite sequence of gas-fired boiler control. Those systems are likewise sensitive to the steam header pressure but are arranged to control the boiler outlet damper to produce an air flow through each boiler in proportion to the steam demand. In such cases the gas valve is made responsive to furnace draft in order to keep the quantity of gas in step with the quantity of air. Such gas valves can be diaphragm- and pilot-actuated or be lever-operated by a regulator which balances the furnace draft against an actual gas flow differential.

Obviously, only one steam pressure element can be used to control several boilers, all supplying steam to a common header. Two or more pressure elements would cause objectionable hunting between boilers jockeying for the load. Therefore, where the pressure controller is on an individual regulator or valve, that valve must be on the gas supply line before it divides to serve the individual boilers. Hand valves are provided in the gas lines to the individual boilers to proportion the gas quantity and the load between those boilers. Likewise, those systems which vary the flow of air through the boiler in ac-

* Excerpts from a paper presented at the A.S.M.E. Spring Meeting, Houston, Texas, March 23–25.

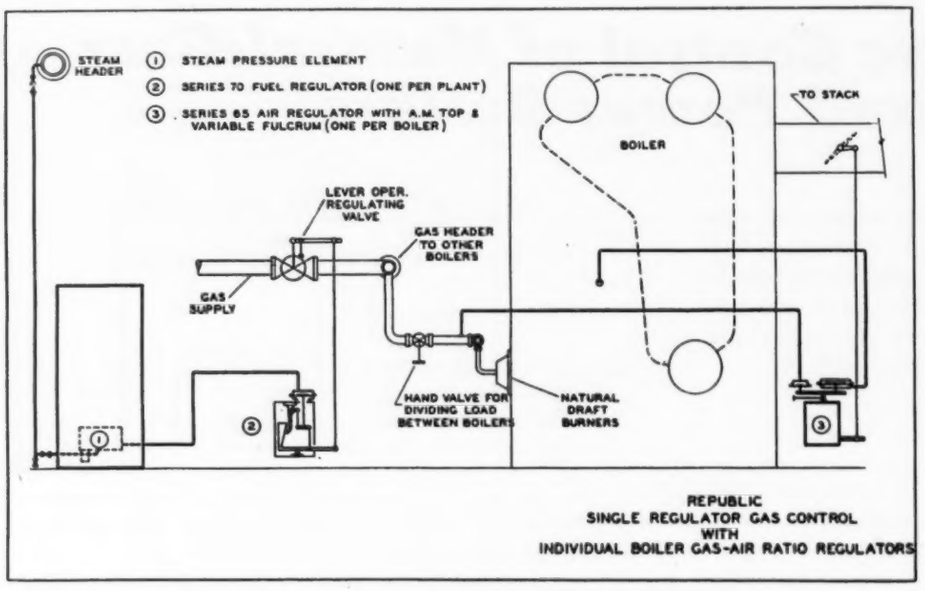
STEAM HEADER
① STEAM PRESSURE ELEMENT
② SERIES 70 FUEL REGULATOR (ONE PER PLANT)
③ SERIES 65 AIR REGULATOR WITH A.M. TOP & VARIABLE FULCRUM (ONE PER BOILER)
TO STACK
BOILER
LEVER OPER. REGULATING VALVE
GAS HEADER TO OTHER BOILERS
GAS SUPPLY
HAND VALVE FOR DIVIDING LOAD BETWEEN BOILERS
NATURAL DRAFT BURNERS
REPUBLIC
SINGLE REGULATOR GAS CONTROL
WITH
INDIVIDUAL BOILER GAS-AIR RATIO REGULATORS

Fig. 1—Typical complete master-loaded control system

cordance with steam demand must use a single steam element with a suitable system to operate the dampers of the several boilers in the desired load ratio.

A master steam element, providing loading impulses to individual boiler gas regulators or diaphragm valves, gives the greater flexibility of proportioning the load between the individual boilers. Proper-sized valves can then be selected for the firing range of a single boiler. Manual fuel control and load proportioning can then both be remotely accomplished from a panel-mounted master control station.

Maintaining Proper Combustion Conditions

Combustion control is the second function of boiler controls. Efficient burning of the gas assures lowest cost of steam, greatest steam production from the available boiler plant, longest life of furnace refractories, saving in pipe line capacity and conservation of gas. There are almost as many arrangements of regulators for maintaining the best combustion, as there are makes. For brevity only a few that are typical will be considered. These parallel the gas flow plans just discussed and might be divided in three groups:

1. Air flow master loaded in step with the gas flow.
2. Air flow actuated direct from the gas flow.
3. Gas flow controlled direct from the air flow.

Master-controlled combustion air regulators are actuated simultaneously with the gas-flow regulators from the steam-pressure element, so that the same changes are made in the gas as in the air flows. As gas burners are the carburetors of the boiler furnace, the proper mixture is then assured for all throttle openings, and correct combustion is maintained at all boiler ratings.

A complete master-control station is provided with a manual adjustment of this ratio of gas to air, so that this ratio may be reset from this panel-mounted control station, should changes in gas or boiler conditions warrant. Suitable indicators are usually provided at such stations showing the exact ratio of the gas and air flows being maintained. Parallel tube-type indicators simplify reading the ratio.

Such a complete master station gives the operator complete centralized control of the boiler operation. In addition to the fuel–air ratio adjustment, control wheels are provided for dividing the load between the boilers in any desired proportion. A panel-mounted remote manual control station enables the operator to place instantly any one of the boilers on manual control from that station, independent of other boilers, which may be on automatic steam-pressure control. As boiler instruments will be mounted on the same panel, the operator can observe any need for occasional closer adjustment, and the results of any remote manual control of the regulators.

From a complete master control station, individual loadings are dispatched to the individual gas-flow and air-flow regulators of each boiler. Such regulators balance this master loading against measurements of the flows being controlled. The advantages are thus obtained of measured control.

Fig. 1 illustrates such a complete master-loaded control system typical of a great many installations. Here the gas regulator balances gas differential against master loading and the air regulator balances boiler differential against its master loading.

Where complete master control stations are not desired, but where certain advantages of the steam pressure element and some panel-mounted control are to be retained, various modified arrangements are used.

In one such modified master system, which resembles the control system being supplied for the boilers of a large Texas defense plant, the individual boiler gas-flow regulating valves are individually loaded from the plant steam pressure unit on the master control panel. Manual stations are supplied on the panel for remote manual control of any gas valve, and handwheels permit dividing the load between the boilers in any desired proportion. Air flow is kept in measured proportion to this gas flow by regulating the boiler outlet damper. This regulator is actuated by any unbalance between the gas-flow and the air-flow measuring elements, and the best gas–air ratio can be set by a convenient handwheel adjustment of the variable fulcrum on the weigh-beam, balancing these two measuring elements.

One of the simplest arrangements of control for natural-draft boilers is shown in Fig. 2. It is typical of a great many installations on smaller boilers and employs a steam pressure element which transmits a loading impulse to a receiving regulator which operates a single valve in the gas header to one or several boilers; it thus supplies the total quantity of gas required to maintain steam pressure. As the load is varied automatically the several boilers divide this load in whatever proportion is deter-

mined by the setting of the hand valve in the gas lines to the individual boilers. Air flow regulation by each boiler damper is identical to that just described, with the gas–air ratio adjustment provided on this air flow regulator.

Correct measurements of the gas and air quantities are essential to accurate combustion control. While the orifice plate is the basis for flow measurements, it can be used in only a few boiler gas and air measurements. In Fig. 1, it was noted that the gas was measured by an orifice in the individual boiler gas line in the complete master controlled system. There the corresponding air flow is measured by the differential through the boiler. These total quantities of gas and air are then balanced against the requirements as brought to the individual regulators by the master loading pressures. As each is a measurement of total flow, the number of burners or air louvers in service does not affect the gas and air differentials or their ratio.

In many modified control systems gas measuring orifices are not used and the gas flow to each boiler is measured by the differential pressure drop through the burners. A fixed burner is an accurate differential measuring element, and with burner header pressures of several pounds, this header pressure is proportional to the square of the gas flow. The air-flow regulator then balances this pressure against the draft in the furnace. The fixed air register openings of the burner provide the same accurate differential measuring element for the airflow.

Putting individual burners in and out of service on a multi-burner controlled boiler introduces the problem of a changed differential measuring element. This is applied to both the gas and the air sides of the burners. Where the gas burner pressure and the furnace draft are the measurements of the gas and air flows, more or less burners will not affect the gas–air ratio, if the usual practice is followed to close completely the individual air register when the corresponding burner is taken out of service. There will then be the same number of air-measuring registers as gas-measuring burners, and the same gas–air ratio setting will produce the same combustion conditions. Such features of design minimize the need for re-adjustment for common operating changes.

The gas–air ratio adjuster, on the regulator of modified systems, or on the panel of master-controlled systems, provides quickly accessible adjustment of this ratio whenever burner, register, boiler or other changes are made in fuel or firing conditions. The combustion meter shows the operator whether or not the correct excess air and CO_2 are being maintained by the control.

On some types of measuring regulators this gas–air ratio adjustment is simply a handwheel moving a variable fulcrum of the balanced weigh-beam, thus changing the relation of the gas and air flow forces. An indicating scale aids the operator in resetting at any desired ratio. Such a combustion regulator is equipped with a suitable power element to operate the boiler outlet damper or other means of varying the air flow until the measurement of that air flow balances the fuel flow impulse on the weigh-beam of this regulator. Stabilizers, mechanical connections between the pilot valve and the damper or other compensating devices, give the desired combination of sensitivity of measurement, speed of response, together with complete stability, and freedom from hunting and over-travel.

Each make of regulator has individual design features and many claimed advantages. Those most common as used on power boilers accomplish these desired features of accuracy, sensitivity, speed, power and stability by various means. The best regulators, of course, are those that accomplish all without sacrificing any of those desirable features.

Control With Forced-Draft Burners

In the foregoing the common condition of natural-draft burners and stack-draft boilers has been assumed. In the case of forced-draft burners, the identical control is used for gas quantities and combustion air flow, except in the detail of air measurement. The differential between the pressure in the burner box and the draft in the furnace provides good air measurement and the ratio usually need not be reset when burners and their individual registers go into and out of service. These air measurements can also be made across the boiler or air heater as previously mentioned.

Forced-draft firing requires one more regulator per boiler than does natural draft. Air is forced into the boiler in addition to the action of the stack draft or an induced-draft fan in drawing the products of combustion through the boiler and out to atmosphere. As one regulator is already being actuated by steam demand and

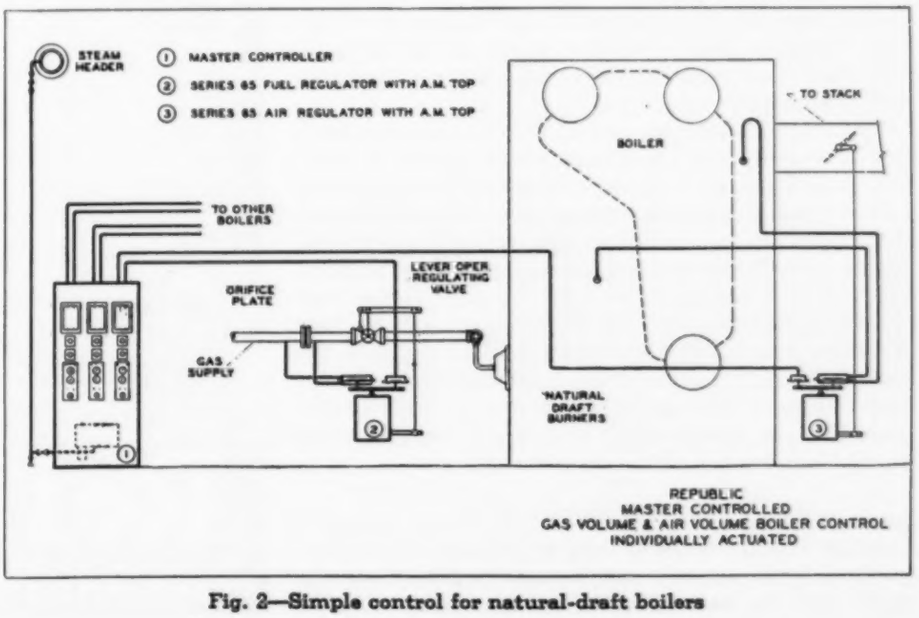

Fig. 2—Simple control for natural-draft boilers

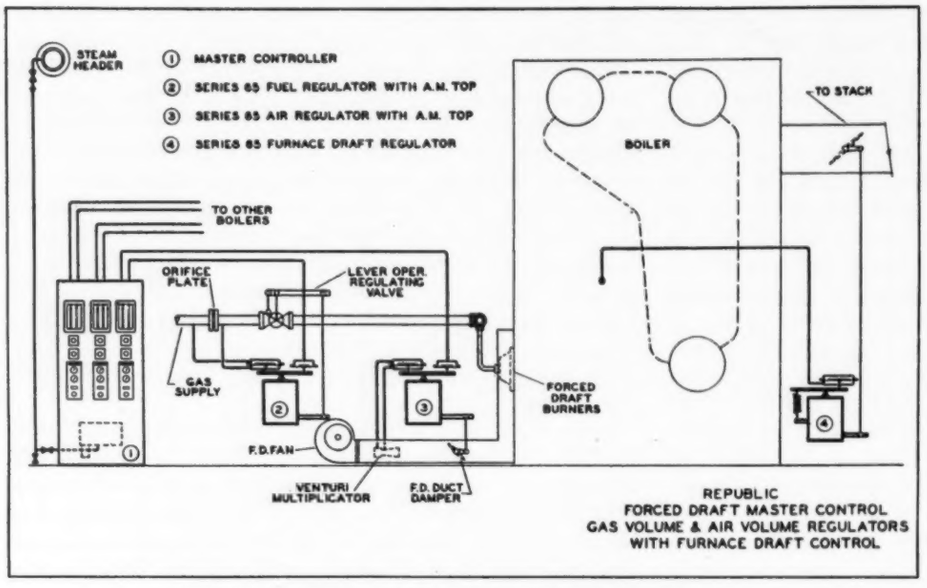

Fig. 3—Complete system of control with forced draft

the second regulator follows the first to keep the air flow in step with the gas flow, the function of this third regulator is to maintain a constant draft in the boiler furnace.

Whether this furnace-draft regulator actually operates the forced-draft fan or damper to control the forced air supply to the boiler, or whether it operates the induced-draft fan or the boiler damper to vary the flow from the boiler, is merely an engineering choice. Advantages are claimed for the latter arrangement, as then the gas and air supplied to the burners are under primary control from steam pressure and the furnace-draft control merely follows. There is a safety advantage here, as this furnace-draft regulator is then independent of the other parts of the control system and has the single function of preventing positive furnace pressure by operation of a damper or fan.

Furnace-draft regulators require the same highly sensitive draft measuring elements, stabilizers and mechanical return connections, as described for combustion regulators. Excess suction in the furnace increases air filtration, while positive pressure in the furnace reduces the life of refractories and causes puffing.

Fig. 3 shows a complete forced-draft, natural-gas-fired, control system, including furnace-draft regulation. This system is actuated from a panel-mounted master controller, responsive to steam pressure. This is shown complete with manual station, boiler rating ratio valves, gas–air ratio valves and parallel-tube loading indicators. The gas-flow regulator balances measured gas flow against master loading; the forced-draft regulator balances measured air flow against master loading, while the furnace draft is regulated by operation of the boiler outlet damper. Somewhat similar systems with forced-draft fans and furnace-draft control are being installed at two large bomber plants in the Southwest.

Safety Requirements

Safety regulators are a very important part of any gas-fired boiler control, and warrant a more thorough study than can be included in this discussion. Briefly, however, two serious conditions must be prevented, namely, low gas pressure and flame extinguishing. Obviously, either might permit an explosive mixture of gas and air to accumulate which might result in a damaging explosion when ignited.

Pressure safety regulators are the simplest. The common purpose of all is to shut off the gas completely from all the burners when the pressure of the gas drops to a predetermined minimum. Most such devices have a lock which prevents these valves from opening again until manually reset, thus preventing the gas from reaching the hot furnace until an operator is at hand to provide safe ignition. These devices vary from weight-operated valves on individual burners, all electrically actuated from a gas-pressure device, to a safety regulator which actuates a master control system to close all its regulating valves when gas pressure fails.

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A Guide for Inventors

By L. T. Parker, Attorney
Cincinnati, Ohio

Articles pertaining to patents have appeared in these pages from time to time. The present discussion, however, has been arranged as a guide for those engineers who may contemplate applying for a patent by pointing out what things are and are not patentable and the various factors that govern patentability. Commonplace examples are cited and each point is verified, by reference to reports of higher court decisions as listed in the bibliography.

THINGS which are *definitely* unpatentable are as follows:

An idea
A scientific principle
A result or function
A property of matter
An aggregation of parts
A system
Devices having an immoral object
Devices created by mechanical skill
Equivalents to other and known products
And all things or devices that do not possess any utility

The following things *generally* are unpatentable:

Devices produced by changing the form of an old invention
Devices produced by changing the size of an old invention
Devices produced by changing the material of an old invention
Devices produced by changing the location of the parts of an old invention
Devices produced by a transposition of the parts of an old invention
Devices produced by duplicating an old invention

While these usually are unpatentable they may be patented if any of the following advantages are produced by the change.

If new and beneficial results are attained (1)[1]
If an old result is attained in a more facile, economical and efficient way (2)
If a new mode of operation is involved (3)
If the invention has proved of great utility (4)

Prior Use

The prior use in a foreign country of an invention not patented or described in a printed publication does not invalidate a United States patent if the inventor did not know of its use previous to his invention (5). However, if a person other than the inventor has filed an application for a U. S. patent and has built and used an embodiment of the invention prior to the inventor's conception, or (6) if the machine or article has been built and put into actual and practical public use prior to the inventor's application for a U. S. patent, this constitutes an anticipation (7).

[1] Figures in parentheses refer to bibliography at end of article.

If the device was merely an experiment and was not successfully operated or was an abandoned experiment it has no anticipating effect (8).

Anticipation of a patent should be established, not merely by testimony of witnesses relating to facts many years previous, but by concrete, visible contemporaneous proofs, and the proof must establish a clear connection; and something more than oral testimony is required when considerable time has elapsed (9).

Mechanical Skill

The mere adaptation of means, such as would occur to any mechanic is *not* invention (10); as for instance: making an old article adjustable, stronger, larger or longer, or making in one piece that which formerly was in two pieces, or *vice versa* (11), or making a square article round. Using I-beams instead of channel beams, or increasing the number of parts, does not require inventive genius and, therefore, is not patentable.

However, simplicity is often mistaken for "mechanical skill." But to obtain absolute simplicity is the highest trait of genius (12) and if by simplifying a machine the result is attained in a cheaper or otherwise advantageous way, it is patentable (13). Sometimes an apparently very slight improvement of an article results in a most valuable patent, as where a new and useful result is accomplished which was sought for by skilled mechanics for years without avail (14, 15).

The mere adoption of common expedients in adapting an existing machine to a new use is invention, where the thought of the adaptation is new (16). For example the mere placing of graduations or marks on a spindle is mechanical skill, but if the inventor has the idea of their adaptation it is invention, and especially where a new function is performed (17).

Systems

Systems generally are not patentable, as for instance: The *idea* of printing an advertisement upon a bill book does not involve invention and, therefore, is not patentable, but an advertising device made of cardboard is an

article of manufacture and patentable as such, if novel and involving invention (18).

Bookkeeping systems or business systems are not patentable but mechanical aids to such systems are patentable. Also, the *means* of carrying out a system, such as a restaurant check on a piece of cardboard with printed matter thereon, is patentable (19). A street car transfer is patentable (20) and is termed an article of manufacture.

A system of transacting business disconnected from the *means* for carrying out the system is not within the most liberal interpretation of the term and art, and unless the *means* used are novel and disclose invention, such a system is not patentable (21).

Change of Material

The use of a different material in the construction of an article previously patented involves invention only when it produces a new and useful result or increased efficiency, or accomplishes a decided saving in operation (22), or where a superior product results (23); also, if new results are attained which render the article for the first time successful in operation (24).

Change in Form or Shape

Mere change in form or location of an element is not sufficient to avoid infringement or to obtain a patent (25), where the mode of operation or a similar function is performed in substantially the same manner; but if dissimilar in form and function it is valid and patentable and avoids infringement (26).

Changing the location of a part which when changed operates on the same principle as previous to its transposition will not avoid infringement (27).

To replace a bearing made in one section by a bearing made in two sections does not require invention (28); nor does making a device arc-shaped instead of square to avoid strain (29).

Utility

An invention is deemed useful; when it will operate to perform the functions and secure the results intended and its use is not contrary to public health and morals (30).

The term useful as contained in the patent law, when applied to a machine, means that the machine will accomplish the purpose practically when applied in industry. If it operates only in a crude way it is deemed useful (31, 32).

A device, to be patentable, must be useful; that is, it must have utility. A patent for a belt that was constructed in such a manner as to protect the heads of the rivets used to splice the belt, was declared void. This is so because it was shown that the rivet heads did not need protection (33). The patent, therefore, being useless was not valid.

And so it is with inoperative devices, such as so-called perpetual-motion machines. They are considered impractical, useless and not patentable, unless a working model could be submitted to the Patent Office, for the purpose of demonstrating its operativeness, which, of course, cannot be done where no outside source of power is utilized to overcome the friction of the moving parts.

In questions of infringement, a person who appropriates and uses a patented device cannot question its usefulness or utility (34, 35), and this is so, even if the infringer found it desirable to use additional apparatus in connection with the invention. The infringer cannot set up the plea that a device has no utility because the owner has made and ceased to make the article.

Amendments

Amendments are that part of the procedure in obtaining a patent which consists of a revision of the claims, or specification, or drawings or all, and arguing the case by correspondence.

After the patent application is prepared and mailed to the Patent Office, in due course of time a notice is received by the inventor or his legal representative acknowledging receipt of the papers. After a period of time the papers are carefully examined by the Patent Office official and if any patents or references are discovered to be pertinent to the invention in question, the claims thus deemed anticipated are rejected. It is then that considerable skill and efficient preparation of amendments by correspondence may be necessary to obtain a patent broadly and have it advantageously covered. Sometimes the preparation of an amendment requires more painstaking efforts and consumes more time than the preparation of the original application.

Reissue Patents

A reissue patent, contrary to the idea of many persons, does not extend the duration of a patent. A United States patent issues for 17 years and cannot be extended except by an act of Congress.

A reissue patent is one which is issued after the surrender of the original patent to the Commissioner of Patents. It issues for the duration of the time the original patent had to run and only when, through oversight, accident or mistake and without any fraudulent or deceptive intention on the part of the inventor, the original patent failed to give the proper protection (36, 37).

A reissue patent is authorized by plain terms of the statute and by a long line of decisions of the Supreme Court where the original patent fails clearly and adequately to secure an invention and where the unquestionable object and effect of the reissue is to cover an invention not covered by the original claims (38).

Good faith is necessary on the part of the inventor applying for a reissue patent and if secured through fraud it is invalid (39, 40).

A reissue patent cannot be defeated by a patent to another person issued *before* the reissue, but *after* the original patent on which it is based (41).

Where, through a mistake on the part of the Patent Office, a patent is issued having misprints, another patent or a reissue will be granted the patentee at the expense of the Patent Office (42).

It is not necessary that the patent be *wholly* inoperative or invalid, as even an obvious error in a drawing is proper subject for a reissue, or failure to make claims of sufficient breadth may be regarded as inadvertence, accident or mistake resulting in a defective and insufficient specification (43, 44, 45).

Where it is found that the original patent was not invalid from a defect or insufficient description, or from defective or insufficient claims, there is no right to a reissue patent and it is invalid (46).

It is well-settled law that to warrant the valid reissue of a patent there must not only have been a mistake by the patentee, with no want of reasonable diligence in its discovery, but also that no third person has in the meantime acquired the right to manufacture and sell what the patentee failed to claim (47, 48).

A reissue patent is rendered invalid by a long delay in making application therefor, in the absence of special circumstances excusing the delay, particularly where the claims are broadened. Two years' delay is usually sufficient to invalidate a reissue patent but where the claims are diminished this rule does not apply (49).

A lapse of eight months between the date of issue of the original patent and the date of application for a reissue is not unreasonable and under special circumstances it has been held that a delay of seven and one-half years does not invalidate the reissue (50).

However, the settled doctrine has come to be that a delay of more than two years from the original patent's date of issue and the date of application for a reissue, in the absence of special circumstances, renders the reissue patent invalid (51).

An infringement suit cannot be maintained on an original patent which was surrendered to receive a reissue or where a reissue is applied for (52). This is known as "intervening rights." In such cases new matter may not be admitted into the specification and claims, although shown in the drawings (53). Under such conditions the claims cannot be broadened. However, if the invention has not gone into general public use between the date of filing the original patent application and that of filing the reissue application, the claims and other parts of the specification may be broadened (54), provided the matter claimed was disclosed in the original application (55). Merely filing an application by another without manufacturing the article does not constitute intervening rights (56). The fact that some of the claims may be too broad and invalid does not invalidate other claims. The claims may be either narrowed or broadened to express the real invention as disclosed in the original application (57).

Duplication

A device comprising mere duplication of old parts is not patentable. However, an invention comprising a duplication of parts may be patentable if the device produces not mere duplication of product or result but a new utilitarian result (58).

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Avoiding Deposits and Corrosion in Regenerative Type Air Preheaters

The March issue of COMBUSTION contained an article by this author dealing with the most effective methods of cleaning the surfaces of the regenerative type of air preheater. Complimentary to this are means for reducing or preventing deposits and corrosion in such preheaters. This latter subject was discussed by the author in a paper presented at the recent Spring Meeting of the A.S.M.E. at Houston, Texas, of which certain excerpts are here given.

By JOSEPH WAITKUS

The Air Preheater Corporation

EXPERIENCE indicates that control of temperatures is the most effective method for reducing and possibly completely eliminating difficulties with deposits and corrosion. Five methods have been developed for application to air preheaters and are generally accepted as means of establishing the desired control. Each of the methods will accomplish the same results but they differ in principle and possibly in the cost of installation.

Cold Air Bypass System

This method of temperature control is illustrated in Fig. 1. The principle is based on reducing thermal recovery in the air preheater by reducing the quantity of air absorbing heat. The exit gas temperature becomes higher resulting in a higher mean temperature at the cold end of the heating surface.

A portion of the air for combustion is directed through a small duct and subsequently mixed with preheated air. There is only one limitation as to location of the bypass duct. The distance between the windbox and the point in the preheater air duct where the cold air is admitted should be sufficient to assure complete mixing of cold and preheated air to attain a uniform temperature. Otherwise, stratification may cause some difficulty with combustion.

Dampers are indicated at the air inlet to the air preheater and in the bypass duct and are essential to the proper operation of the air bypass. They provide control of air distribution between the air preheater and the air bypass over the full operating range of the equipment to which the air preheater is applied. For example, when a steam-generating unit is operating at low load the quantity of air to be bypassed may be great and the resistance through the bypass duct may be greater than through the air preheater.

The damper at the air preheater inlet provides means for increasing the resistance there, making the bypass more effective. At high capacity in the steam-generating unit, the air bypass will not be necessary and the damper in the duct serves to close the system.

The chief advantages of this method of temperature control are, first, the simplicity of the arrangement and, second, during starting up periods all the air can be by-

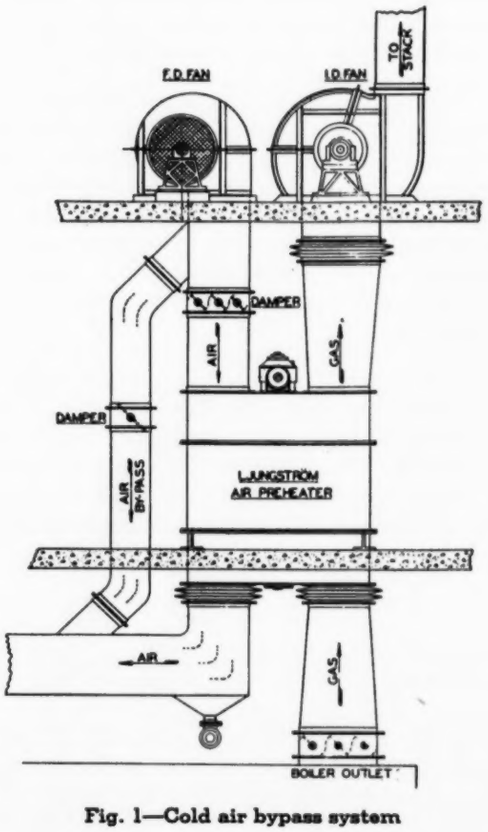

Fig. 1—Cold air bypass system

passed and the air preheater protected to the fullest extent. There are two disadvantages. First, the temperature of air for combustion is lowered by mixing with cold air. This may not be serious for secondary air, but for primary air it may lead to difficulties in the mills es-

pecially if the fuel is high in moisture. Second, there is a loss in efficiency resulting from the higher exit gas temperature. This may not be a serious matter unless it is necessary to bypass air at the normal operating load.

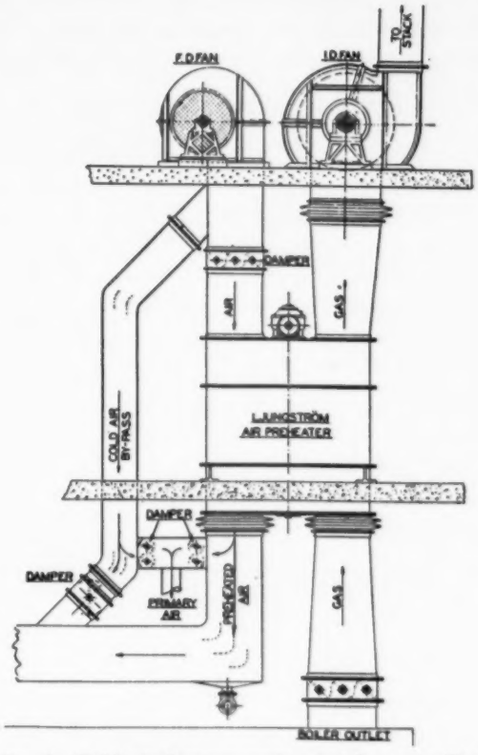

Fig. 2—Cold air bypass system with controlled primary air temperature

Most operators, however, are not concerned about efficiency at loads lower than the normal load.

Cold Air Bypass System With Controlled Primary Air Temperature

To overcome the difficulty of low primary air temperature as indicated above, the Cold Air Bypass System was modified as illustrated in Fig. 2. A cross-over duct was provided between the cold air bypass and preheated air ducts. With the aid of dampers in the cross-over duct a mixture of cold and preheated air can be obtained to suit any desired primary air temperature up to preheated air temperature.

Hot Air Recirculation System

This system is illustrated in Fig. 3. It provides a duct extending from the preheated air duct to the forced-draft fan inlet. Preheated air is drawn through the duct and mixed with cold air drawn through the usual inlet of the forced-draft fan. Turbulence usually present in the fan results in a fairly uniform mixture of preheated and cold air. The result is an increase in the temperature of the air being directed to the air preheater. Increasing the air temperature raises the mean temperature of the cold end of the heating surface accomplishing the same result as the Cold Air Bypass System.

Dampers are required in the recirculating duct to shut off the system and in the preheated air duct to control distribution when operating at low capacity. At low capacity, the damper in the preheated air duct will provide resistance to air for combustion. Speeding up the forced draft slightly will overcome this resistance and increase the suction in the recirculating duct.

The main advantage of the hot air recirculating system is that very little change will be noted in the gas temperature. In other words, the increase in quantity of air passing through the air preheater is very nearly compensated for by a lower rise in air temperature thereby maintaining the same heat balance between air and gas as existed without recirculation. The efficiency is therefore not lowered enough, if any, to be a serious matter. The outlet air temperature is higher due to the higher inlet air temperature which may be desirable from the standpoint of primary air.

The disadvantages are, first, due to the temperature of recirculated air, the duct will be large in cross-sectional area, as much as twice the size of a cold air bypass duct for the same duct velocity. Second, there is a slight increase in air pressure loss through the air preheater due to increased quantity and temperature of the air. The increase in volume increases the power consumption accordingly. Third, during starting-up periods, enough preheated air is not available for recirculation to elevate the inlet air temperature sufficiently to obtain the desired protection.

When hot air recirculation of this type is adapted to an existing installation, the following should be kept in

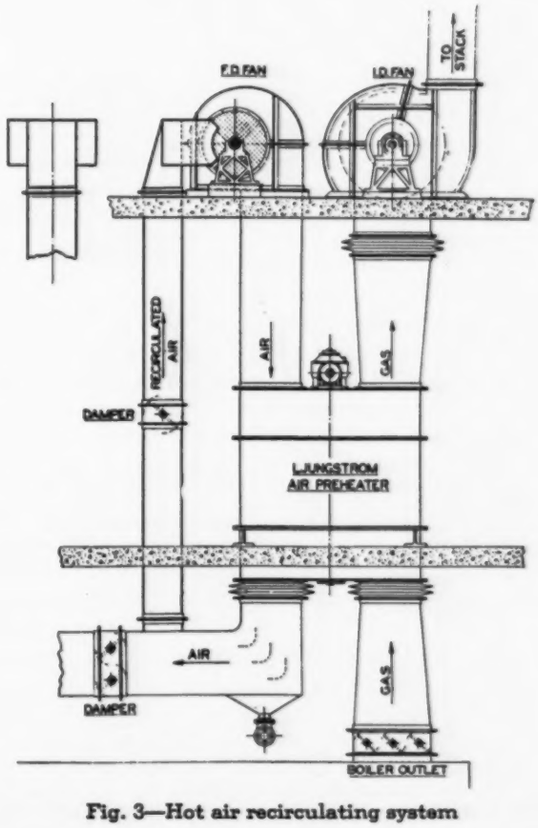

Fig. 3—Hot air recirculating system

mind. Some difficulty may be experienced with overloading the fan as a result of the increased volume to be handled. The introduction of preheated air in the forced-draft fan designed for cold air may lead to some difficulty with the fan. This system cannot be adapted

to a fan equipped with inlet vane control. At low capacity the vanes tend to close and would accordingly reduce the suction on the recirculating duct making it ineffective.

Hot Air Recirculation System with Separate Fan

In view of the difficulties with the application of the preceding system of temperature control, a modification illustrated in Fig. 4 has been made. A separate fan is included for recirculating the preheated air. This fan is selected for high temperature air and when equipped with variable-speed drive permits control of recirculated air quantities.

An important feature of this system is the possibility of directing the recirculated air into the most effective point of the air preheater. In the regenerative type air preheater the heating surface cools gradually as it moves through the air stream. It is in the coolest state when it is about to enter the gas stream. A division plate across the air duct restricts the recirculated air to a definite region and prevents diffusion over the entire duct area. Preheating the heating surface just before it enters the gas stream is very effective.

The total power consumption in the hot air recirculating system will be in favor of a separate fan arrangement. The recirculating fan operates against a resistance equal to the loss through the air preheater plus a small duct loss whereas in the previous system the forced-draft fan operates against the total resistance of the entire forced-air system.

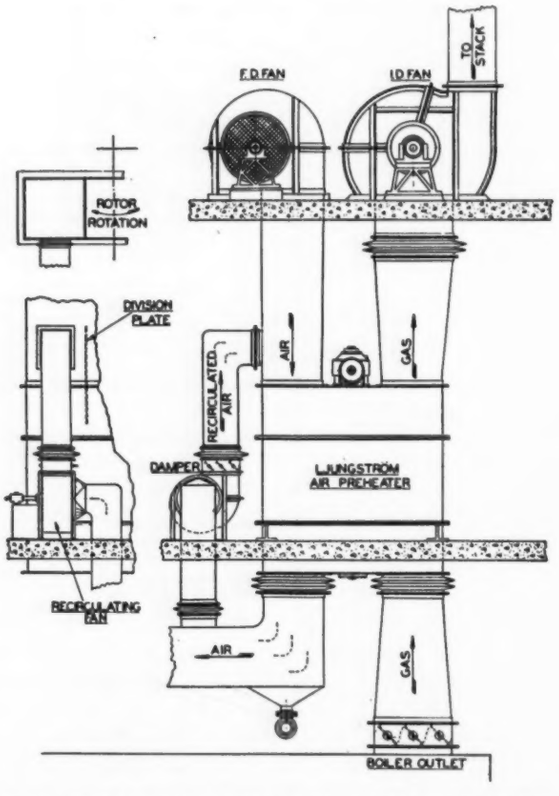

Fig. 4—Hot air recirculating system with separate fan

The cost of this installation is greater than that of any one of the previous systems due to the recirculating fan.

Gas Bypass System

This system of temperature control, as illustrated in Fig. 5, is interesting but not generally employed. It is applicable to steam-generating units which include an economizer ahead of the air preheater. At low capacity the economizer is not so essential to efficiency. With an arrangement of dampers the gases are divided so that a portion passes through the economizer while the remainder bypasses the economizer. Gases at a higher temperature are directed to the air preheater inlet resulting in a corresponding higher exit gas temperature and mean temperature at the outlet end of the heating surface.

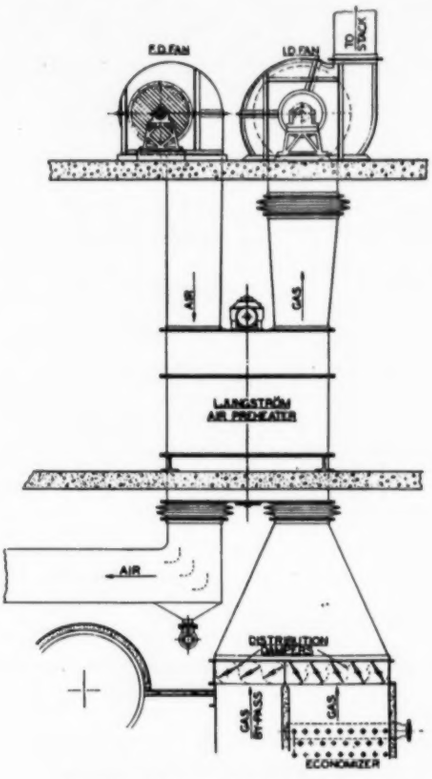

Fig. 5—Hot gas bypass system

This method of temperature control requires close attention to the division of gases; otherwise, the economizer may, if the feedwater temperature is low, suffer corrosion for the same reasons that it occurs in the air preheater.

There are undoubtedly other methods of temperature control just as effective, each the result of a development intended to take advantage of some existing condition. For example, in one installation the boiler walls were air cooled under natural circulation. The warm air was wasted until a duct was provided between the wall outlet and the forced-draft fan inlet. The innovation provided more and better circulation through the air-cooled walls and utilized the waste heat to good advantage in protecting the air preheater by providing air at a higher temperature.

Up to this point no mention has been made of the quantity of air to bypass or recirculate. These quantities should be calculated to suit operating conditions at each installation.

The performance with cold air bypass and hot air recirculation is compared with normal operation in Fig. 6. The comparison is based on a typical application of a regenerative type air preheater to a steam generating unit having a maximum evaporation of 400,000 lb of steam per hour and using fuel with 4 per cent sulphur. Calculations are based on the performance at 150,000 lb per hr evaporation.

Note that recirculation requires a larger quantity of air than cold air bypassing; that the exit gas temperatures for recirculation approximate the normal operating value, whereas that with cold air bypassing is somewhat higher; that the air temperature for combustion in cold air bypassing is lower than in normal operation, whereas that with recirculation is not quite so low. These differences become more pronounced as the calculations are extended to lower evaporations.

Comparing the forms of the curves in Fig. 6, note the amount of curvature in each of the three cases. Cold air bypassing results in a greater curvature than normal operation, whereas hot air recirculation results in less curvature. As the ratio of the product of air quantity and specific heat to gas quantity and specific heat approaches 1.00 the curves tend to flatten out. At a ratio of 1.00 they are straight lines parallel to each other and the metal temperature curve is the arithmetical mean of the gas and air temperature. Generally, the ratio is less than 1.00 and the metal temperature curve is not exactly midway between the air and gas curves but is slightly above.

The regenerative principle produces a variation in metal temperature as the heating surface passes through the air and gas stream. This variation establishes the lowest metal temperature for which the control quantities must be calculated.

The application of cold air bypassing has stimulated interest in automatic control for the dampers. Totalizing the temperatures at the cold end of the heating surface is considered to be the best indication of when cold air bypassing is necessary. It therefore forms the basis for two automatic control systems. Both accomplish the same results and differ only in their method of translating the impulse from thermocouples or thermostats into motion necessary to operate the dampers.

By setting controls at the panel board, an operator can adjust the standard to which the automatic control will function. Noting the evaporation and air temperature at the inlet to the air preheater, the proper totalized temperature can be selected for any capacity on the steam generating unit. The question of human element is thus reduced to a minimum and control from a remote location is readily achieved.

Conclusions

The nature and extent of corrosion and deposits is a function of several factors all of which are variable and lack stability, individually or in combination. Evidence points to the necessity of recognizing the importance of fuel constituents and observing the temperatures at the cold end of the heating surface of the air preheater more regularly.

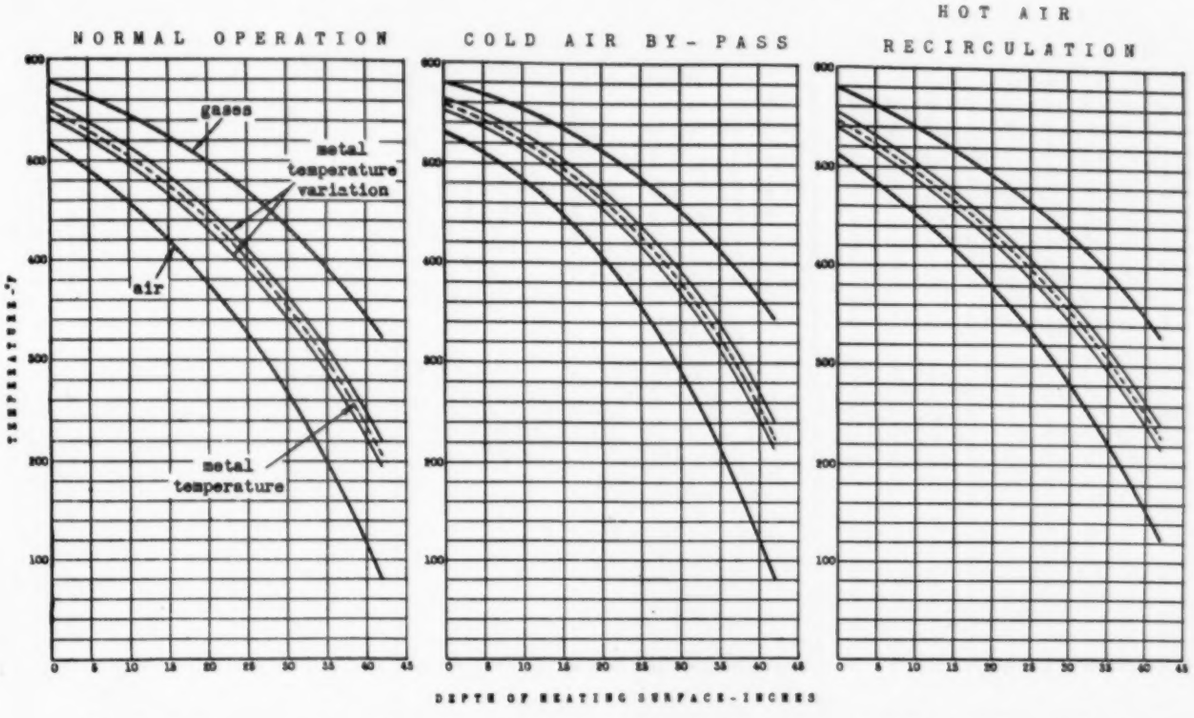

Fig. 6—Performance with cold air bypass and hot air recirculation compared with normal operation

Of the several methods of temperature control, the cold air bypass system lends itself most readily to installation for a very nominal cost. The results have been encouraging and are receiving more and more recognition. With automatic damper control included, it should be possible to obtain the most exact control over corrosion and deposits.

There is a distinct necessity for more research and investigation of methods for determining the exact temperature at which condensation will take place in the gases. At present, the empirical methods leave a great deal unaccounted for and omit consideration of many influencing factors.

NEW CATALOGS AND BULLETINS

Any of these publications will be sent on request

Air Compressors

Radial type two-stage air compressors, for 80–125-lb pressure, are described in a new 8-page bulletin (H-620-B16F) received from the Worthington Pump and Machinery Corporation. Salient design and construction features are shown in photographic halftones and cut-away views. Dimension sketches and tables are also given.

Centrifugal Pumps

The Ingersoll-Rand Company has issued a new 12-page bulletin (No. 7167) which illustrates the features of its Class GT two-stage centrifugal pumps. The bulletin contains photographs and cross-sectional views, performance tables, and a comprehensive tabulation showing friction of water in various sizes of pipe. The text describes many structural details of the pumps, and cites many industrial applications which have been found for this type of unit.

Combustion Control

The Brooke Engineering Company has just issued a 42-page bulletin (No. 15) describing its various systems of automatic combustion control for all sizes of boilers. Construction details of regulator units are dealt with and the use of a master pressure is discussed. Position control is described and typical applications to small boilers using either natural- or forced-draft firing are given. The fuel–air ratio system is described as applied to traveling-grate and multiple-retort stokers, and also the electric-eye system of combustion control for pulverized coal, oil and spreader stoker firing. This is a profusely illustrated bulletin containing many cut-away views and dimension drawings of equipment, also control panels, chart records, and installation views and diagrams.

Fans and Blowers

The third edition of "Standard Methods Adopted for Centrifugal Fans and Blowers" (Form X-12), published by the National Association of Fan Manufacturers, is now available. The new form includes standards for multiblade and non-overloading types of fans; air density ratios at different altitudes and air temperatures for use with the chart on Classes I, II, III and IV fans; comparison charts for industrial fans and cast-iron volume fans.

Vacuum Pumps

An 8-page bulletin (L-710-B1) has been issued by the Worthington Pump and Machinery Corporation which describes its line of single- and two-stage horizontal dry vacuum pumps. The bulletin is illustrated with photographic halftones of belt- and steam-driven pumps, and cut-away views of pump cylinders and other details.

Temperature Control Instruments

The Leeds & Northrup Company has just issued a 16-page catalog, N-33-163(1), which describes the Micromax temperature control system for superheated steam. Schematic diagrams show how the control is being applied to different types of boilers, and reproductions of chart records illustrate actual operating results. Also pictured and described is a supplementary control for topping units which, when the load drops off, acts automatically to prevent exhaust steam temperature from rising excessively and damaging the low-pressure turbine.

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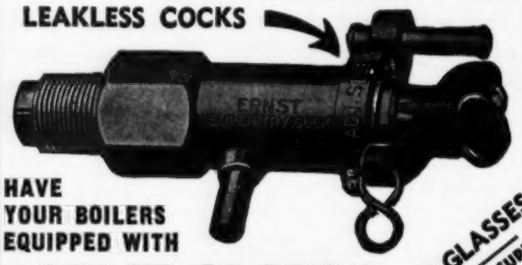

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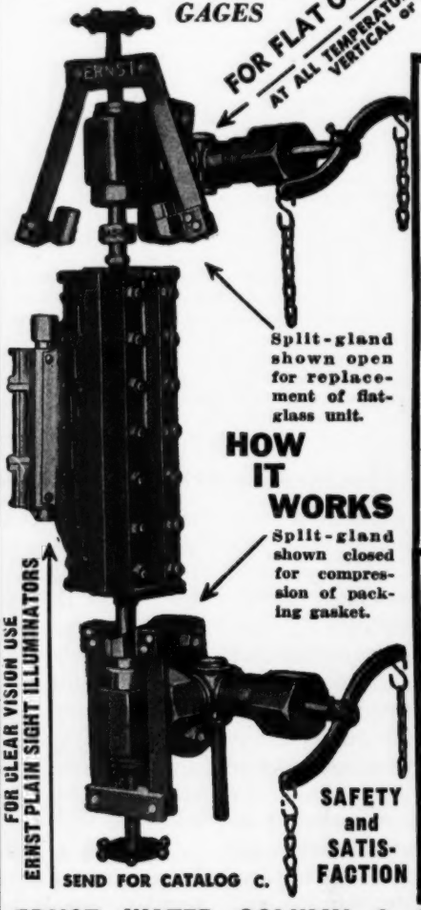

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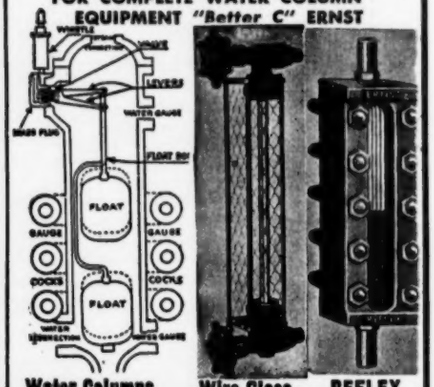

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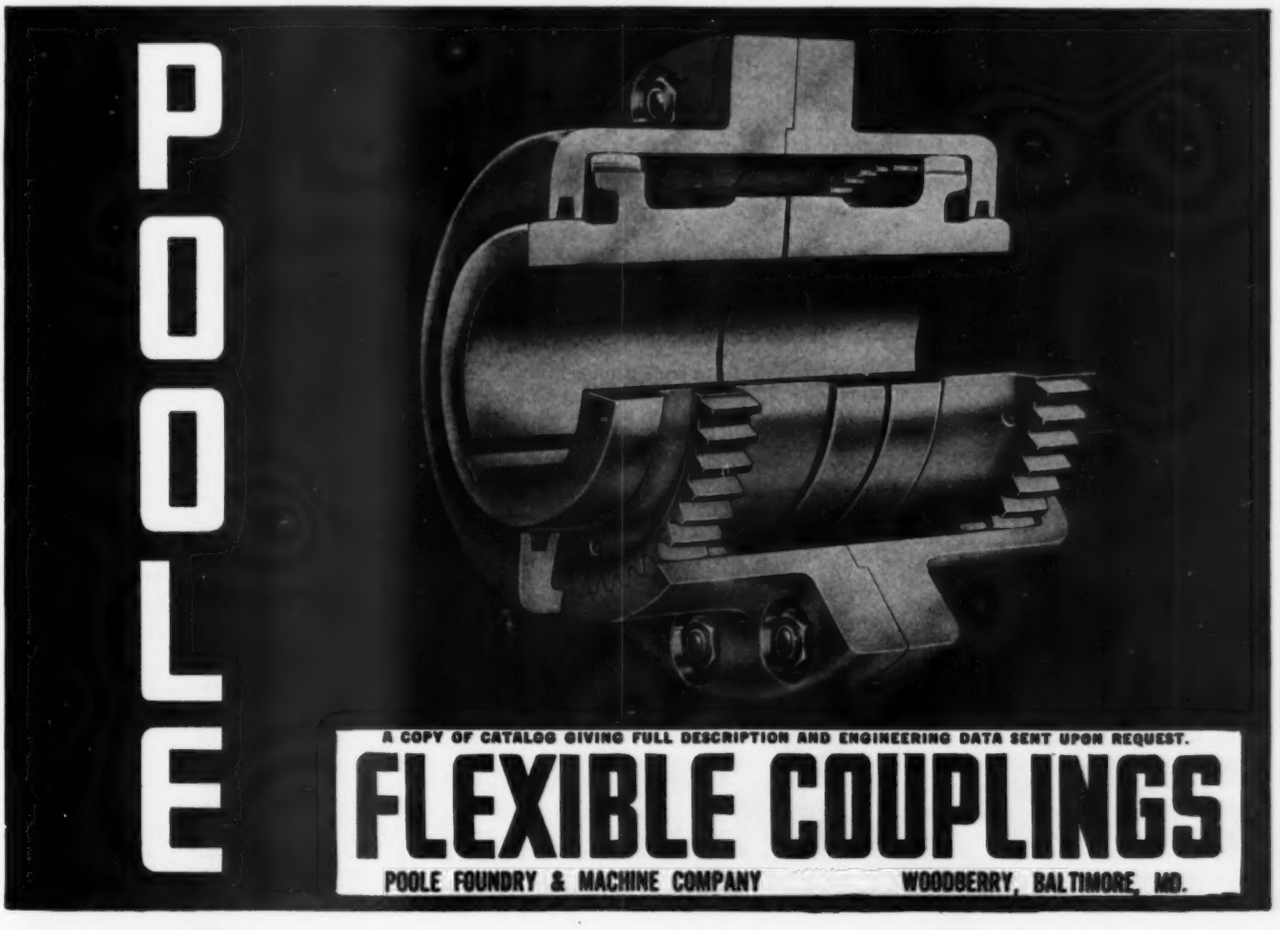
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FLEXIBLE COUPLINGS
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ALEX DOW

Alex Dow, for many years president of the Detroit Edison Company and for the past two years chairman of the executive committee, died of pneumonia on March 22, in his eightieth year. He had been active until a week before his death.

Mr. Dow was born in Glasgow, Scotland, and came to the United States when he was twenty years old. His first six years in this country were spent in the employ of the Baltimore & Ohio Railroad, and the next five years with the Brush Electric Company which was engaged in making equipment for street lighting systems. He next became associated with the design and construction of the original lighting plant in Detroit and in 1896 was made vice president and general manager of the Edison Illuminating Company, Detroit, the predecessor of the Detroit Edison Company of which he became president in 1913.

Although not a graduate engineer, Mr. Dow acquired a very thorough and intimate knowledge of engineering details which always claimed his closest interest, despite the broader aspects of his executive duties. His advanced thinking along engineering lines was responsible for his company becoming, some years ago, a pioneer in the use of large boiler units and the application of underfeed stokers to such units.

He was regarded as one of the outstanding utility leaders and was conspicuous for his broad-gage views on matters pertaining to public relations and the development of rate schedules upon which he was looked upon as a leading authority.

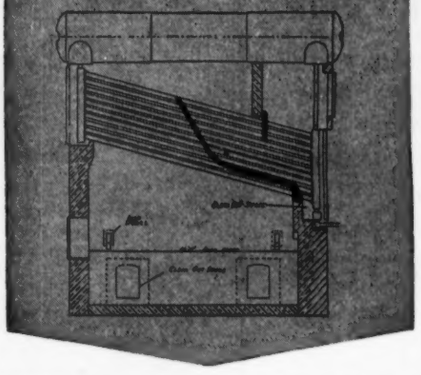
Among the many honors that had been conferred upon him were honorary engineering degrees from several universities and the 1936 Edison Medal. He was a past president of the American Society of Mechanical Engineers and of the Association of Edison Illuminating Companies, a fellow of the American Institute of Electrical Engineers, a member of the American Society of Civil Engineers and the Institution of Electrical Engineers of Great Britain.

For the past ten years Mr. Dow had served as chief of the Detroit District of the U. S. Ordnance Department and up to a week before his death had been giving most of his time to this important war work.

To Guard Against Inflationary Coal Prices

Arrangements have been announced by which the Bituminous Coal Division of the Department of the Interior and the Office of Price Administration will cooperate in taking steps to prevent wartime inflationary prices for bituminous coal. The Office of Solid Fuels Coordination already has extensive data on the coal production costs in all districts and has been directed to obtain, from public and private sources, information as to military and civilian needs. It will further obtain from the solid fuel industries information as to production, available supply and the transportation of such fuels. Recommendations based on these data will be forwarded to the Office of Price Administration for appropriate action.

ANY type of boiler will deliver MORE POWER at LESS COST with Enco Streamlined BAFFLES

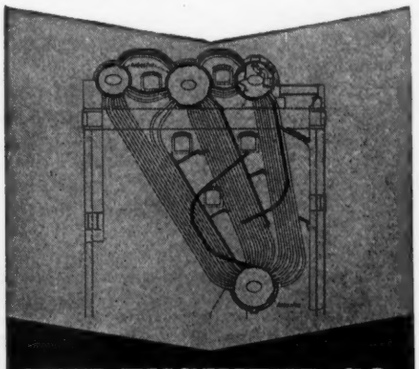


THE cross-flow principle of Enco Streamlined Baffles with its higher efficiencies, may be applied to any type of boiler—horizontal or vertical, straight or bent tube.

By streamlining and curving, gas passages are tapered to maintain velocity as the gas volume is reduced, resulting in a higher rate of heat transfer to boiler and superheater surfaces, and lower flue gas temperatures.

Enco Streamlined Baffles reduce draft loss by eliminating eddy currents, bottlenecks and dead gas pockets—save steam because soot blowers work less often and more effectively.

Ask for Bulletin BW-40 containing valuable engineering data on modern baffle wall construction—It's free.



THE ENGINEER CO.
Enco 75 West St. New York, N.Y.

Revised Priority Rating Affecting Repairs

The War Production Board has lately revised Preference Rating Order P-46 which, it will be recalled, was issued last September to assist utilities in obtaining materials necessary for maintenance, repair and operation. That order assigned a blanket preference rating of A-10 to such materials.

In the amended order the blanket A-10 rating is replaced by two higher ratings. These are an A-2 rating, granted to the delivery of material for maintenance, repairs and operating supplies for power plants and pumping stations, and an A-5 rating which is applied to other facilities such as lines, pipes and substations. One of the reasons for the distinction is that if a power plant or pumping station breaks down the whole system may be affected, whereas if a power line or a water pipe is disabled only a part of the system is affected. In either case the rating is high enough to make possible prompt repair.

The order also assigns an A-5 rating to delivery of materials to bring electricity, gas or water to war plants and for materials needed to protect power plants or pumping stations against sabotage.

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